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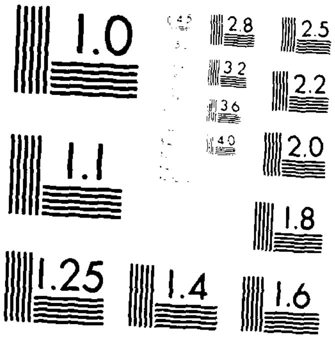

MICROCOPY RESOLUTION TEST CHART

REPORT NO: CG-D-79-81

Hazardous Chemical Fluorometer Development

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16. Abstract

Technical description of a prototype in-situ towed fluorometer for measuring the fluorescence and absorption intensities of hazardous chemicals that could be spilled in the ocean or inland waterways.

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METRIC CONVERSION FACTORS

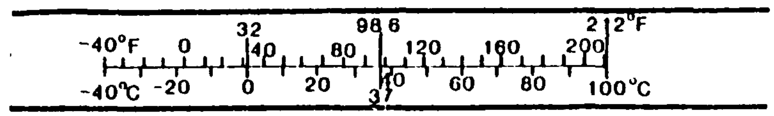
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 Introduction

The Johns Hopkins University Applied Physics Laboratory (APL) has developed an underwater towed fluorometer system that is used to measure the fluorescence of hazardous chemicals spilled in the ocean and inland waterways. This instrument was developed under a contract with The Coast Guard R & D Center, Groton, Connecticut. The contract encompassed a two year period. The first year was devoted to a laboratory feasibility study to determine if the required measuring sensitivity of a specified list of chemicals could be obtained and propose an instrument that could be used to make these measurements. The results of this laboratory study were published in a first year final report, APL Memorandum EEO-80-4. The building of an operational prototype system constituted the second year work.

The following is a final report covering the second year effort. This report describes the Towed Hazardous Chemical Fluorometer System delivered to the Coast Guard R & D Center.

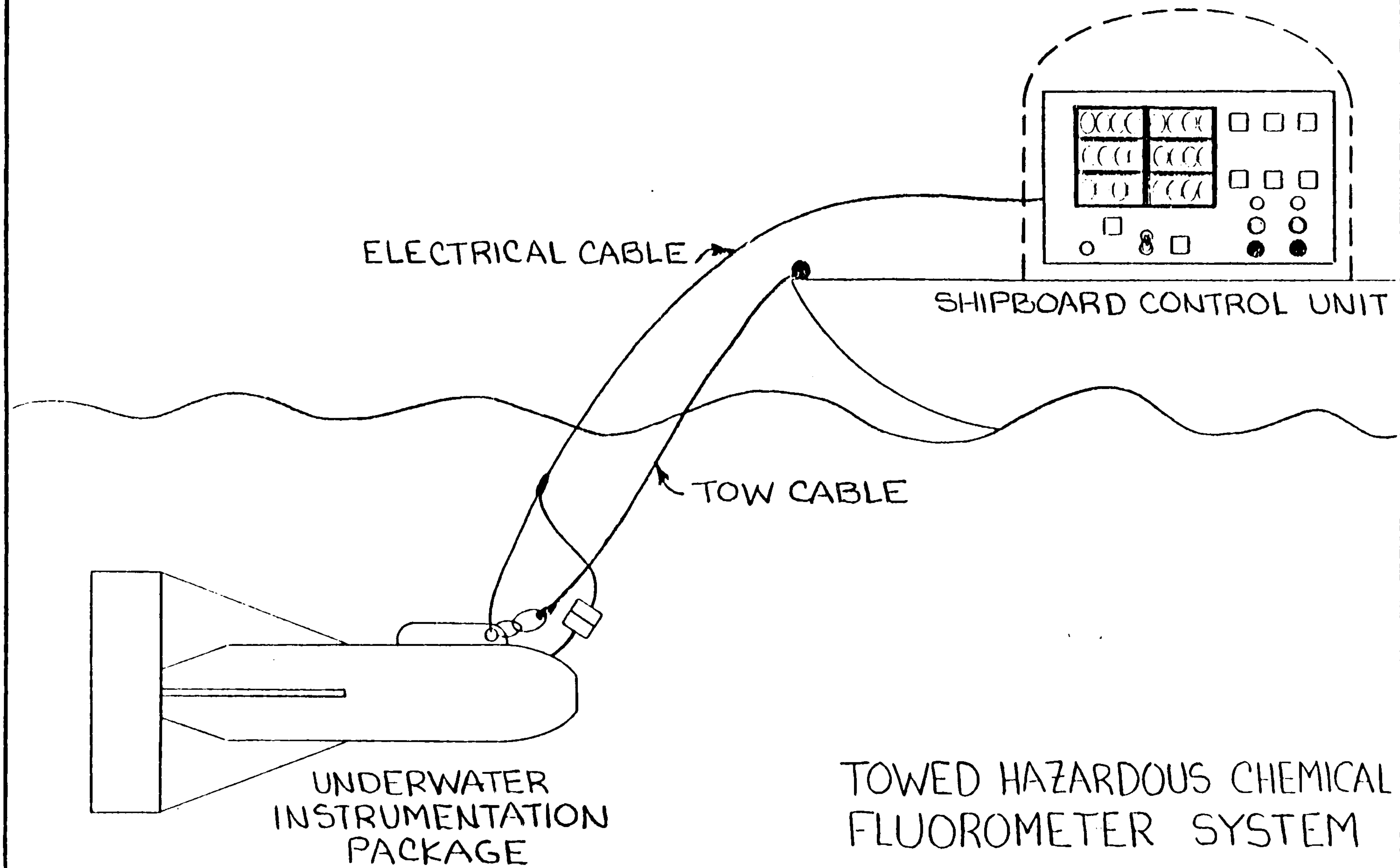
2.0 System Description

The Towed Hazardous Chemical Fluorometer System is designed for underwater measurement of fluorescence and absorption characteristics of chemicals that are excited by ultraviolet light at 253.7 nm and fluoresce in the spectrum between 300 and 400 nm. In addition, the instrument measures turbidity, pH, and temperature of the water as well as the depth of the instrument.

The Towed Hazardous Chemical Fluorometer System consists of an Underwater Instrumentation Package (UIP), a Shipboard Control Unit (SCU), a connecting tow cable, and a connecting electrical cable (Fig. 1). The Underwater Instrumentation Package is designed to be towed through the water to make the measurements and transmit the data to the Shipboard Control Unit.

The interconnecting cable consists of a strength member and an electrical cable for power and signal. The mechanical strength member attaches to a tow point near the center of buoyancy. The instrument has ballast added to the nose and thus acts as its own depressor. The electrical cable contains 3 twisted pairs of conductors: one for power and one each for data up and down links. The electrical cable is terminated in a 7 pin underwater connector which mates to a short pigtail cable from the Underwater Instrumentation Package.

The three sensors that measure temperature, pH, and depth are mounted on the aft bulkhead of the UIP and protrude into a free flooding aft cone. The cone is designed to facilitate flushing of this area while the instrument is being towed. The optics that are used to



TOWED HAZARDOUS CHEMICAL
FLUOROMETER SYSTEM

FIGURE 1

measure the fluorescence, absorption, and turbidity are located internal to the pressure vessel. A flow tube passes through the center of the instrument. The water is forced in the nose and exits at the rear of the aft cone. Inserted in the flow tubes are helical light baffles to block external light from entering the measuring optics. The suite of sensors is conditioned in the instrument package and then digitized and transmitted to the shipboard control unit.

The specifications for the six measurements performed by the instrument are:

Depth: 0-100 meters, $\pm$ .1 meter

Temperature: 0-30°C, $\pm$ .1°C.

pH: 0-14 pH, $\pm$ .1 pH

Fluorescence: Sensitivity = .001ppm (maximum)*

Absorption: Sensitivity = .1 ppm (maximum)*

Turbidity: Sensitivity = 4.0 Nephelometric Turbidity Units (N.T.U.)

*NOTE: The sensitivity of the measurement of fluorescence and absorption will vary with the chemical being measured.

Figure 2 is a block diagram of the Underwater Instrumentation Package. This diagram indicates the major components of this unit which includes the fluorescence/absorption measuring components, turbidity measuring components, temperature, pH and depth measuring components, data acquisition system, and the power system.

The fluorescence/absorption measuring components consist of a mercury vapor light source which requires a high voltage power supply for initial start-up and a low voltage power supply for operation. The low voltage power supply is controlled by a lamp control circuit which monitors the lamp intensity with a photodiode and adjusts the power supply voltage to maintain constant intensity of the light source. The detector used for the fluorescence measurement is a photomultiplier tube. The absorption detector is a photodiode. The photomultiplier tube and photodiode signals are conditioned by logarithmic amplifiers which provide high detection gain for small concentration solutions and a large dynamic range for detection of high concentration solutions.

The turbidity measuring components consist of first a fiber optic cable which couples visible light from the mercury vapor lamp to the turbidity measuring optics. The turbidity measurement is then made using two detectors, both photodiodes. The detectors measure the straight

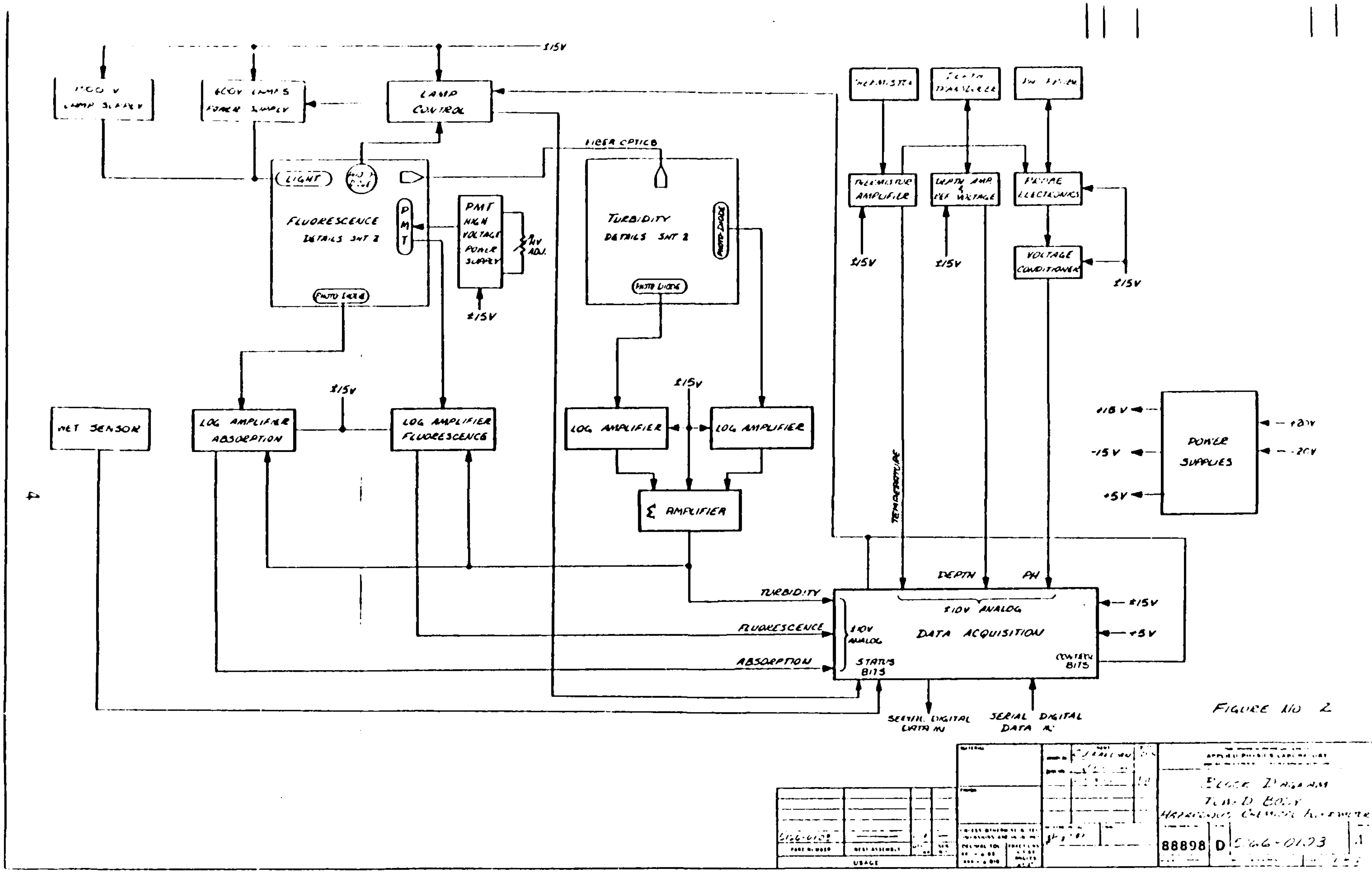


FIGURE NO 2

BLOCK DIAGRAM

88898 D

line loss of light and the scattered light. The signals are then conditioned by logarithmic amplifiers and combined in a summing amplifer to provide a turbidity signal.

The temperature, depth, and pH measuring components consist of a sensor and conditioning amplifiers for each measurement. The amplifiers supply the necessary reference voltages and amplify the small signals from the sensors to a level that is compatible with the data acquistion system.

The data acquisition system accepts the analog signals from the sensors and digitizes these signals to a 12 bit accuracy ($\pm$.05% of the full scale voltage). The digitized signals are then transmitted serially via the data up link to the Shipboard Control Unit. The sample rate of this system can be pre-set to accommodate the desired response of the sensors.

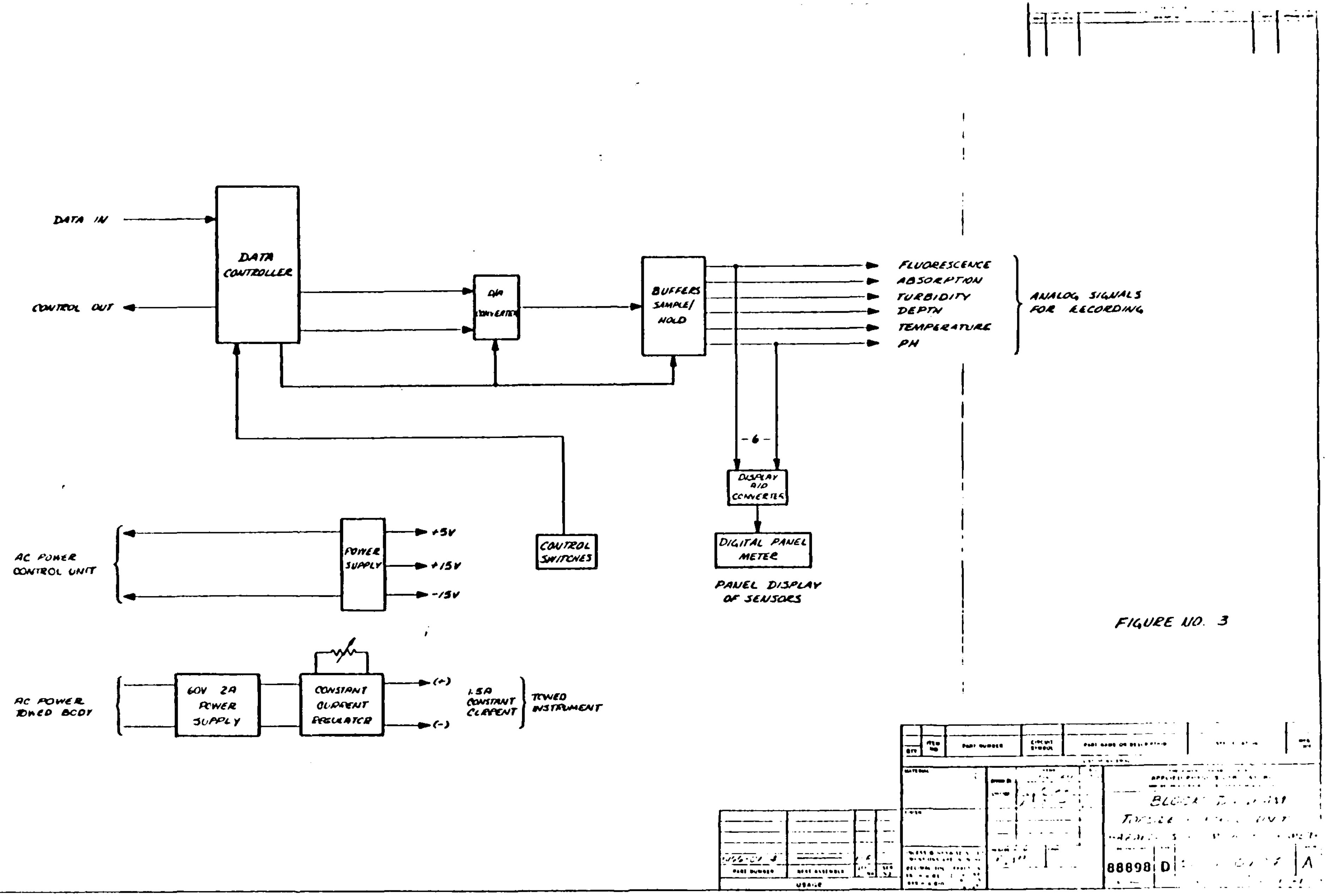
The power system consists of a regulator that converts a 1.5A constant current to a plus and minus 20 volts which is then further regulated to plus and minus 15 volts and plus 5 volts to power the circuits in the UIP. The voltages for the light source and the photomultiplier tube are derived from DC/DC converters.

The Shipboard Control Unit (Figure 3) contains a data controller, digital to analog converter, digital data display, and the power source for the UIP.

The serial data from the Underwater Instrumentation Package is decoded by the data controller and reformatted into a 12 bit data word for each sensor. The data word is then converted to a DC voltage by the digital to analog converter section for use by external data recorders. The digital data display scales the voltages from the digital to analog converter and displays the sensor information in engineering units.

The control switches, located on the front panel of this unit, provide the capability to change functions in the Underwater Instrumentation Package. These functions are converted by the data controller to a digital data word and transmitted serially by the data down link to the Underwater Instrumentation Package.

The power source for the Underwater Instrumentation Package consists of a regulated voltage supply and a constant current regulator.



DATA IN
CONTROL OUT
DATA CONTROLLER
D/A CONVERTER
BUFFERS SAMPLE/ HOLD
FLUORESCENCE
ABSORPTION
TURBIDITY
DEPTH
TEMPERATURE
PH
ANALOG SIGNALS FOR RECORDING
-6-
DISPLAY A/D CONVERTERS
DIGITAL PANEL METER
PANEL DISPLAY OF SENSORS
CONTROL SWITCHES
AC POWER CONTROL UNIT
POWER SUPPLY
+5V
+15V
-15V
AC POWER TOWED BODY
60V 2A POWER SUPPLY
CONSTANT CURRENT REGULATOR
(+)
(-)
1.5A CONSTANT CURRENT
TOWED INSTRUMENT
88898
D
A

FIGURE NO. 3

3.0 Underwater Instrmentation Package Technical Description

3.1 Fluorescence and Absorption Sensors
(Refer to Figure 4)

Figure 4 is a is a functional diagram of the optics used to measure fluorescence and absorption intensity. A mercury arc lamp is used as the light source and is filtered to pass only the 253.7 nm line.

The photodiode detector directly across from the lamp, which is also filtered to pass only the 253.7 nm line, is used to measure the loss of light due to the absorption of the chemicals being measured.

The photomultiplier tube (PMT), which is filtered to provide a bandpass of 290 to 400 nm, is used to detect the fluorescence of the chemicals. The PMT location relative to the light source is 90 degrees.

The photodiode is connected by a fiber optic cable to the light source. It is filtered to respond to the 546 nm line and is used as a monitor of the lamp intensity. The detector output is used to adjust the lamp power to provide a constant lamp intensity.

The windows in this optics block are quartz to minimize the attenuation of the 253.7 nm light and to avoid self fluorescence which would occur if Plexiglass windows were used.

3.1.1 Filters
(Refer to Figure 5)

The criteria for selection of the lamp and absorption detector filters was to provide a very narrow passband centered at 253.7 nm for excitation of the chemicals and attenuation of the other mercury lines. The peak transmission at 253.7 nm is approximately 17.5%. The passband is from 242 to 263 nm.

The filter requirement for the fluorescence detection was to achieve a measuring bandwidth from 280 nm to 400 nm. In addition, the filter must block the 253.7 nm excitation and the longer wavelength lines of the mercury lamp, in particularly the 463 and 546 nm lines. The bandpass was achieved by using a Schott KG1 high pass filter which has approximately 0% transmission at 280 nm with a peak transmission between 350 and 600 nm and a Corning 7-54 bandpass filter with a passband between 230 nm and 420 nm. This combination then provides a detection bandwidth of approximately 280 nm to 420 nm with good attenuation of the 253.7 nm, 463 and 546 nm lines.

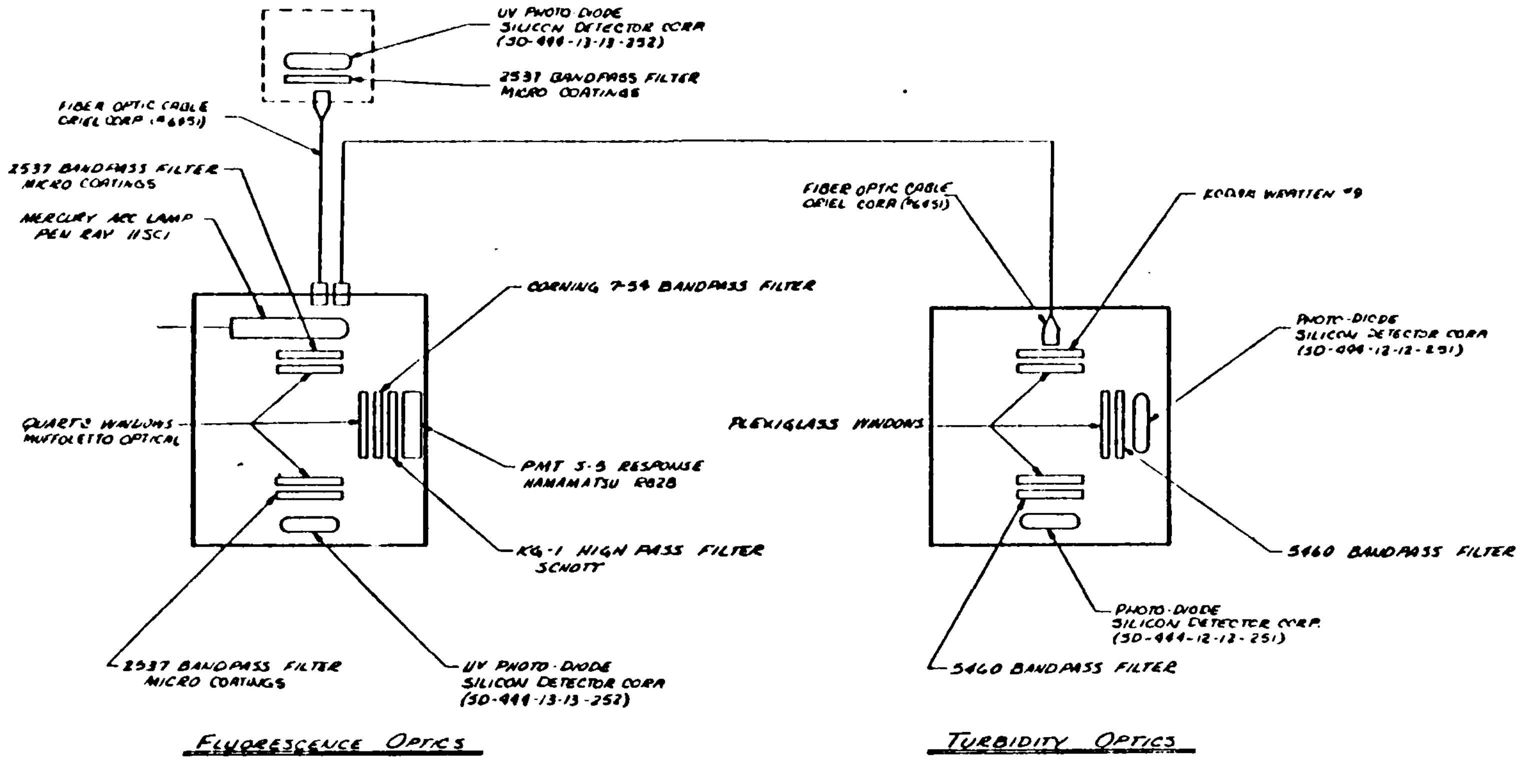

UV PHOTO DIODE
SILICON DETECTOR CORP
(SD-444-13-13-252)
2537 BANDPASS FILTER
MICRO COATINGS
FIBER OPTIC CABLE
ORIEL CORP (#6451)
2537 BANDPASS FILTER
MICRO COATINGS
MERCURY ARC LAMP
PEN RAY 11SC1
CORNING 7-54 BANDPASS FILTER
QUARTZ WINDOWS
MUFFOLETTO OPTICAL
PMT S-5 RESPONSE
HAMAMATSU R828
KG-1 HIGH PASS FILTER
SCHOTT
2537 BANDPASS FILTER
MICRO COATINGS
UV PHOTO-DIODE
SILICON DETECTOR CORP
(SD-444-13-13-252)
FLUORESCENCE OPTICS
FIBER OPTIC CABLE
ORIEL CORP (#6451)
KODAK WRATTEN #9
PHOTO-DIODE
SILICON DETECTOR CORP
(SD-444-12-12-251)
PLEXIGLASS WINDOWS
5460 BANDPASS FILTER
PHOTO-DIODE
SILICON DETECTOR CORP.
(SD-444-12-12-251)
5460 BANDPASS FILTER
TURBIDITY OPTICS

FIGURE NO. 4

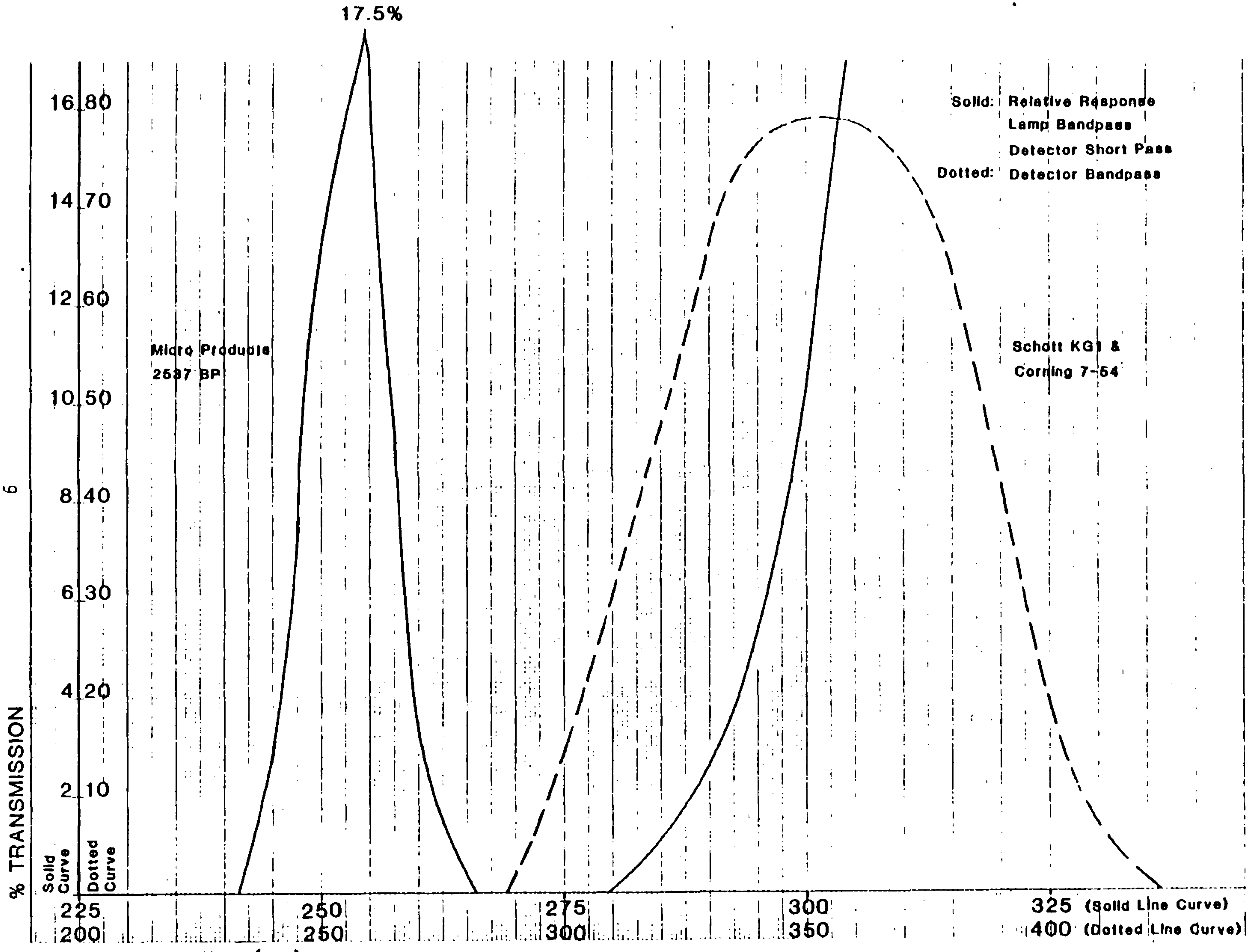


Figure 5: Optical Filters Response Curves

3.1.2. Detectors

Two different detectors are used for the fluorescence and absorption measurements. The absorption measurement uses a Silicon Detector Corp. UV enhanced photodiode. This diode, which is used in the photovoltaic mode, has a response as shown in Figure 6. The diode is one inch in diameter with two active leads of the diode isolated from the case. This configuration allows the diode to be connected in either polarity and with the return lead connected to the case for minimum noise. The fluorescence measurement uses a photomultiplier tube (PMT). The PMT used is a Hamamatsu 1/2" diameter compact tube with a UV transmitting glass envelope. The PMT has a spectral response (Figure 7) from 185 to 650 nm with a maximum response at 340 nm (S5 cathode). The PMT is operated at its maximum supply voltage of 1000 VDC thus achieving maximum gain.

3.1.3 Light Source

The light source is a Pen-Ray Model 11SC-1 low pressure, cold cathode, mercury, gaseous discharge lamp. The lamp generates discrete spectral lines with the strongest being the 253.7 nm line (Figure 8).

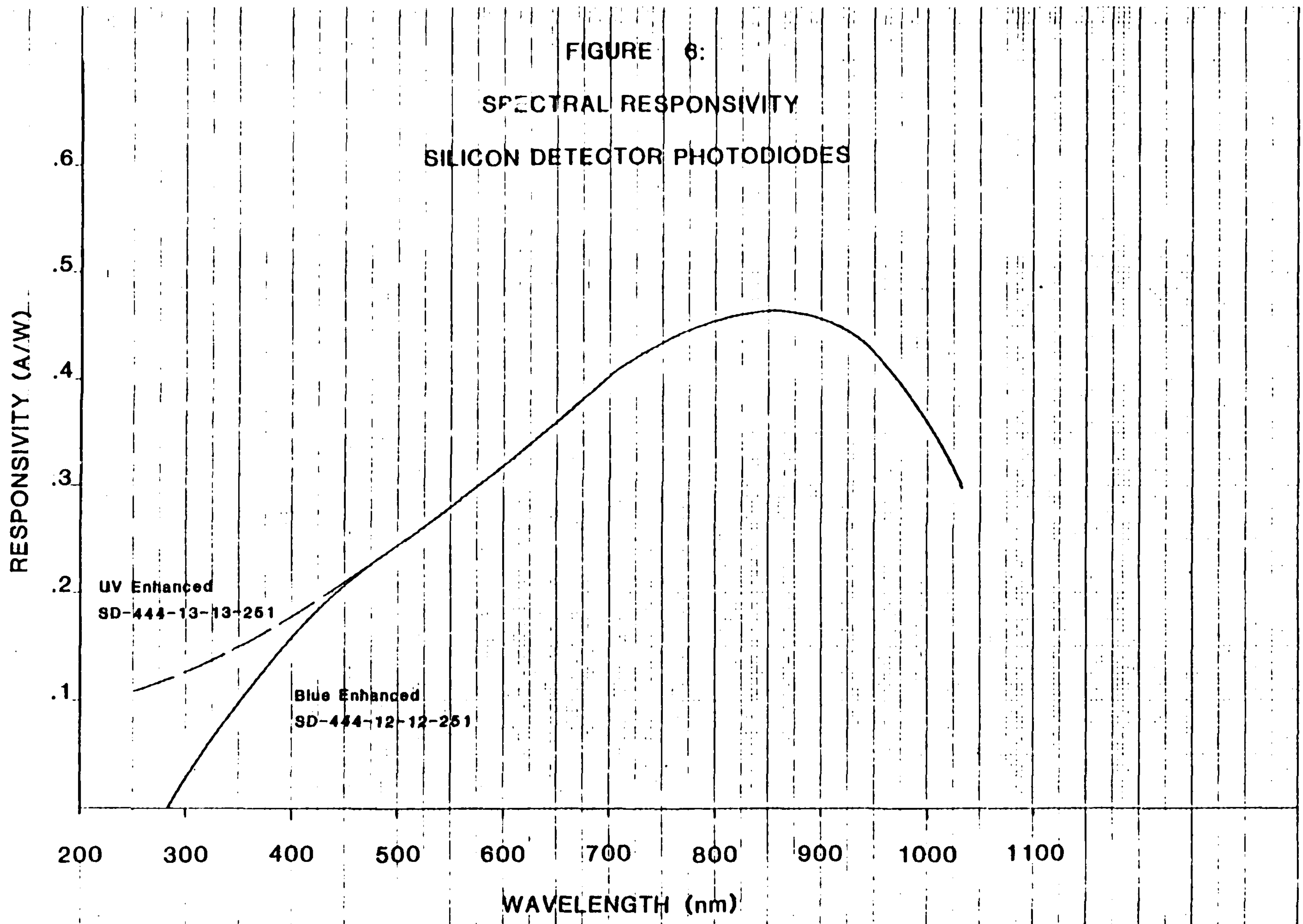
The lamp is operated with a DC voltage instead of the normal AC voltage. The nominal current through the lamp is approximately 18 mA. The intensity of the lamp is controlled by a photodiode monitor and a feedback circuit which controls the lamp current. The operation of this lamp with a DC source will reduce the lifetime due to migration of the mercury to one electrode. This migration will cause a change in intensity and also a shift in the spectral output. Reversing the polarity of the DC source periodically reduces this process. The rated lifetime of the lamp using an AC source is 5,000 hrs. To obtain the same lifetime using a DC source, the current should be reduced by 1/2. The intensity control circuit will compensate for variations in intensity due to the DC operation.

This lamp has 90% of its intensity in the 254 nm line with the balance in the 313, 365, 405, 436, and 546 nm lines. Increasing the lamp current beyond the normal AC current of 18 mA will increase the intensity of the visible lines a greater percentage than the UV line.

3.1.4 Logarithmic Amplifier
(Refer to Drawing 5166-0211)

The amplifiers used for both the absorption photodiode and the fluorescence photomultiplier tube are basically the same except for the input stage. The amplifier configuration as shown in the reference drawing consists of an input stage, a linear fixed gain amplifier, and a log amplifier. The linear amplifier and the log amplifier are included

FIGURE 6:
SPECTRAL RESPONSIVITY
SILICON DETECTOR PHOTODIODES



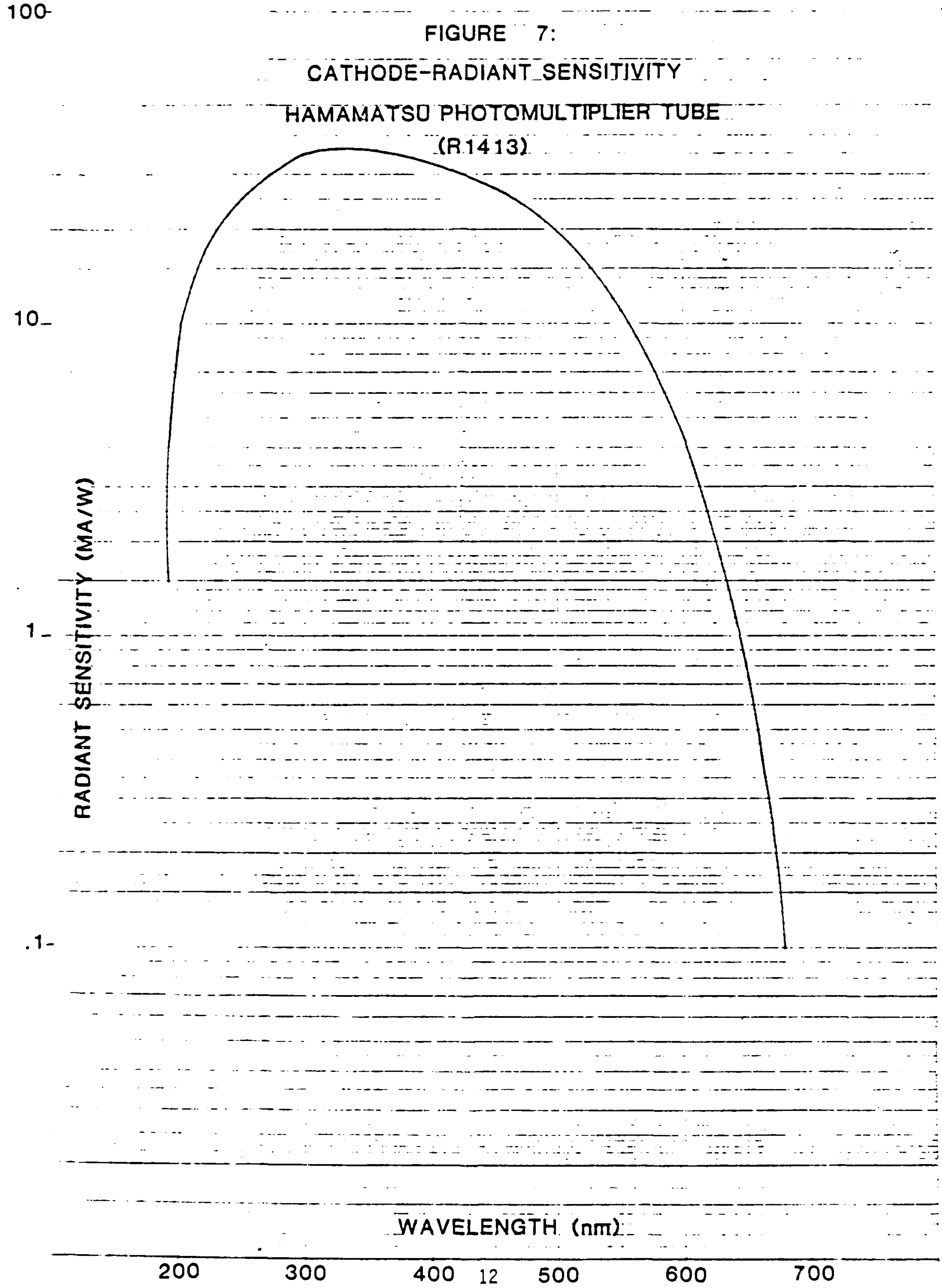


FIGURE 7:
CATHODE-RADIANT SENSITIVITY
HAMAMATSU PHOTOMULTIPLIER TUBE
(R1413)

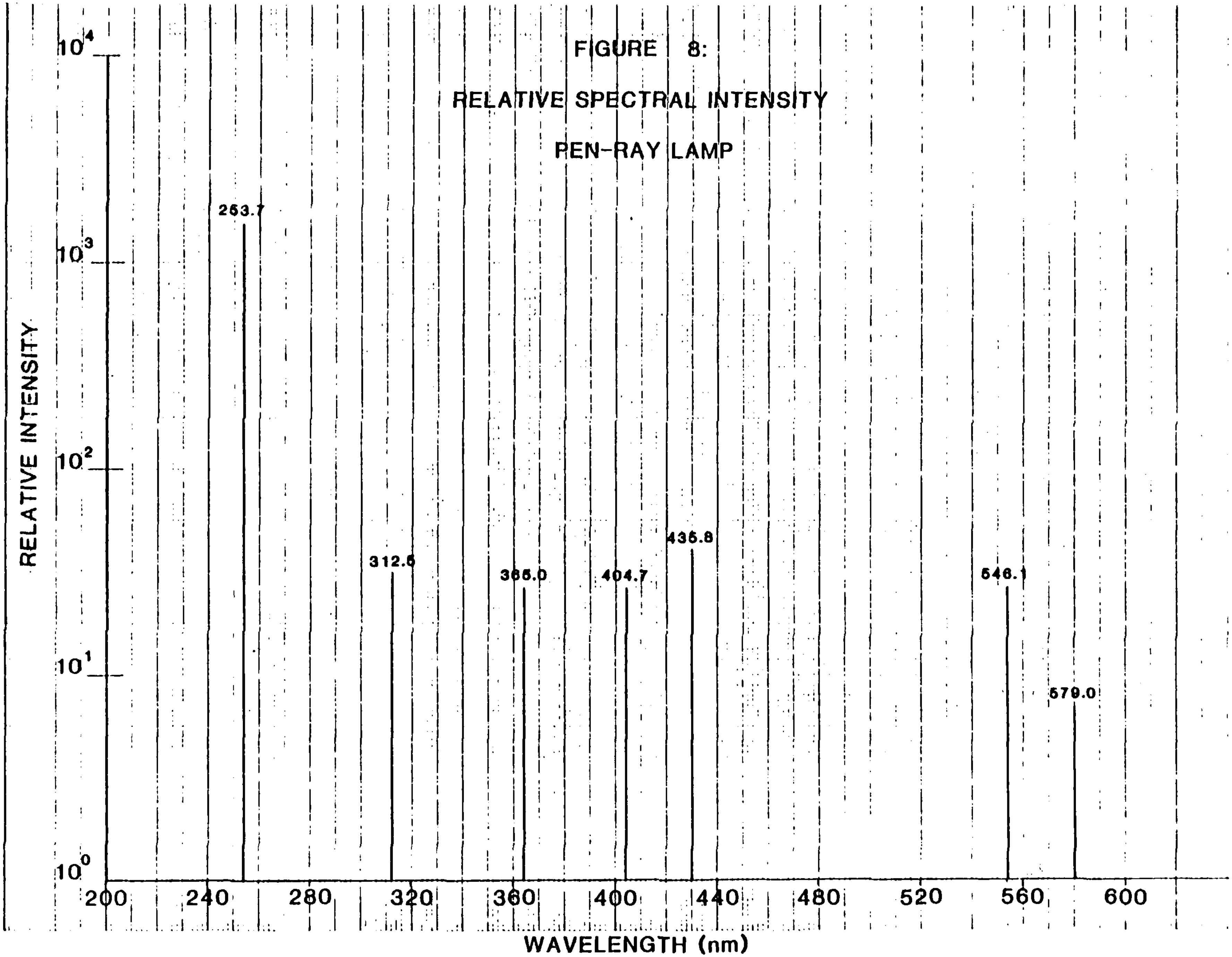


FIGURE 8:
RELATIVE SPECTRAL INTENSITY
PEN-RAY LAMP

in the same package, a Burr Brown 4127 logarithmic amplifier. The linear and log amplifier gains are adjusted so a 1.0 decade change in input current will produce a 5V change in the output voltage. This can be referenced to the output of the input stage where a 1 mV to 10 mV change will produce a 0 to 5V change at the output of the log amplifier Pin A or S.

The input stage for the absorption measurement (IN-1) is a current to voltage amplifier where the output of U1 will be equal to the current through the diode multiplied by the feedback register R1. The input stage for the fluorescence photomultiplier tube (U3) is a unity gain high impedance buffer. Resistor R39 converts the current from the photomultiplier tube cathode to a voltage which is amplified by U3.

The log amplifiers for both sensors have inputs for applying an external offset voltage to set the output to zero volts, compensating for background signals within the sensors. The network associated with this is connected to pin 9. The trimpots, R12 and R13, are vernier adjustments while the coarse adjustment is obtained by connecting R32 and R33 to the offset network. The required offset voltage for the coarse adjustment potentiometer is obtained from the voltage reference source which consists of Q1, a heater controlled precision 10.24 voltage source, and U5. U5 and the associated gain resistors are used to generate plus and minus reference voltages between zero and 10.0 volts. The calibration inputs can be used to insert external voltages to check the operation of the logarithmic amplifier.

The procedure for initially adjusting the operating range of this circuit is to apply an input current to pin 2 of 1×10^{-9} amps or 1×10^{-3} volts to pin 17. These conditions will produce a 1.0 mV signal at the output of the input stage. This will be the minimum input signal. Adjust R12 and R13 to the zero volt point then tailor R3 and R5 (for Channel 1) or R19 and R21 (for channel 2) for zero volts at the output of the log amplifier pins A or S.

The gain of the amplifier is set by the value of resistor R9 or R25. The values shown should result in an output voltage change of 5.0V for a one decade change in input current or voltage.

3.1.5 Light Source Control
(Refer to Drawing 5166-0161)

Referring to Figure 2, the components required to control the light source are a photodiode, the lamp control circuitry, a 600V power supply, and a 1500V power supply.

There are three modes of operation for the light source: start up, constant voltage operation, and intensity control operation. The start up mode is used only when the lamp is initially energized. This mode is controlled by a command from the control unit via the data down link. The characteristics of the lamp require that a high voltage be applied to the lamp for initial ionization, approximately 1500VDC. This step is accomplished by energizing both the 1500V supply and the 600V supply. The high voltage ionizes the lamp, and the 600V supply provides the current to sustain the lamp. Once the lamp is on, the high voltage supply can be turned off. A current sensing resistor and a comparator determine when the lamp is fully on. This indication is transmitted to the control unit via the data up link and lights a "LAMP ON" indicator.

The constant volt operation is used during the turn on sequence and can be manually selected from the control unit via the data down link. This mode of operation places a constant voltage on the lamp, initially setting the lamp intensity to a desired operating point. This mode is desired until the lamp reaches a stable condition. The disadvantage of this operation is that the intensity will change due to lamp heating.

The intensity control operation is used for normal operation of the instrument. In this mode, the desired intensity of the lamp is pre-set; and the photodiode, which is filtered to operate using the 546 nm line of the lamp, monitors the intensity of the lamp. The lamp control circuitry will develop error voltages when the intensity changes which requires adjustment of the 600V power supply to return the intensity to the pre-set value.

The circuitry contained in this section consists of the intensity control circuits (U1 thru U5), relay $K1_1$ for constant voltage control, relay $K1_2$ for lamp-start control, and comparator U9 for sensing the lamp current. The input amplifier U1 is a current to voltage amplifier with a bandpass of 1Hz. The output of U1 is fed to a summing resistor R2. A positive reference source derived from a stable reference network R17, R19, R15, U7 and CR3 is fed to summing resistor R3. U2 amplifies the difference. U3 and U4 amplifies this difference signal by a gain of 190. The output of U4 is coupled to a final stage U5 through relay K1 contacts 2 and 15. U5, which has a gain of 2, provides a reference for loop operation and controls the 600V power supply. When operating in the constant voltage mode U5 receives its input from the voltage divider network R28, R32, and R33 through relay contacts 1 and 15. The voltage comparator U9 senses lamp current through a 240 Ω resistor. Its output goes to a +5V level when the current through the sense resistor produces a voltage that exceeds the reference on U9-3. When K1 is energized, contacts 1 and 15 are connected, placing the system in the constant voltage mode. This causes contacts 14 and 4 to make, placing 5.0 Volts

on the constant voltage indicator line. Kl_2 is the high voltage power supply (H.V.P.S.) relay. When energized, contacts 6 and 12 make, turning on the H.V.P.S. Also, 7 and 9 make, energizing K1, forcing the control to constant voltage operation. A +5.0V level on the H.V.P.S. indicator signal line signifies the H.V.P.S. is operating.

The following procedure is used to adjust the lamp control circuitry:

(1) Select constant voltage mode of operation and connect a meter between R11 (K1 side of resistor) and common.

(2) Adjust R28 for zero volts at this point.

(3) Connect a voltmeter to U5-10 and adjust R16 for -1.9V.

(4) Select the 1200 VDC scale on the meter and connect the meter to the output terminals of the 600V power supply.

(5) Select the lamp start mode and adjust R28 for 600 VDC.

(6) Select lamp control mode operation and adjust R15 for 590 VDC.

3.2 Turbidity Measuring Components (Refer to Figure 4)

Figure 4 is a functional diagram of the optics used to measure the turbidity of the water. This measurement is made by measuring the direct line loss of light from the light source to a detector and comparing it with the increase in light from a detector located 90° from the light source. The light source is a fiber optic cable that couples light from the stable mercury lamp used for the fluorescence measurement. This is filtered to pass the 546 nm mercury line.

Both the inline and 90° detectors are photodiodes and are filtered to detect the 546 nm signal. The 546 nm line was selected because it was readily available and also is outside the sensing bandwidth of the fluorescence measurements, thereby eliminating interference which could be caused by light coupling between the optical systems. The windows used in these optics are Plexiglass. Plexiglass can be used since the operating wavelength of 546 nm is readily passed by Plexiglass and does not cause interfering fluorescence.

3.2.1 Filters
(Refer to Figure 9)

The filters used in this measurement are bandpass filters for the two photodiode detectors and a highpass filter for the light source. The bandpass filters are 3-cavity filters centered at 546 nm $\pm$ 2 nm with a bandwidth of 12 $\pm$ 2 nm. The peak transmission is 60%.

A highpass filter, Kodak Wratten #9, was selected for the light source to attenuate the other mercury lines that are all shorter wavelengths. The highpass filter provides more light intensity in the measuring chamber than a bandpass filter.

3.2.2 Detectors
(Refer to Figure 6)

Both the absorption and scattering detectors are Silicon Dectector Corporation silicon diodes which are enhanced for the blue spectrum. The specifications, except for response, are the same as noted in the Fluorescence and Absorption Sensor Section 3.1.2.

3.2.3 . Light Source

The light source is the Pen Ray lamp used in the Fluorescence and Absorption Optics. (see section 3.1.3). This is coupled to the turbidity chamber by a fiber optic cable. The fiber optic cable, Oriel Corporation part #6451, is 36" long and has a fiber bundle of .125 inches. The transmission spectrum is from 400 nm to 1300 nm. The transmission at the 546 nm wavelength is 50%.

3.2.4 Logarithmic Amplifiers
(Refer to Drawing 5166-0141)

The configuration of the amplifiers for both the scattering and absorption measurements is the same as the one used for the absorption measurement in the Fluorescence and Absorption Section 3.1.4. The only change is that the input amplifier gains are tailored for the different light intensities.

3.2.5 Summing Amplifier
(Refer to Drawing 5166-0171)

The turbidity measurement is actually two measurements; the combination of these measurements is used to define turbidity concentrations. A summing circuit is used to combine the two signals.

The amplifier, as shown on the referenced drawing, consists of an operational amplifier configured as a summing amplifier. The two

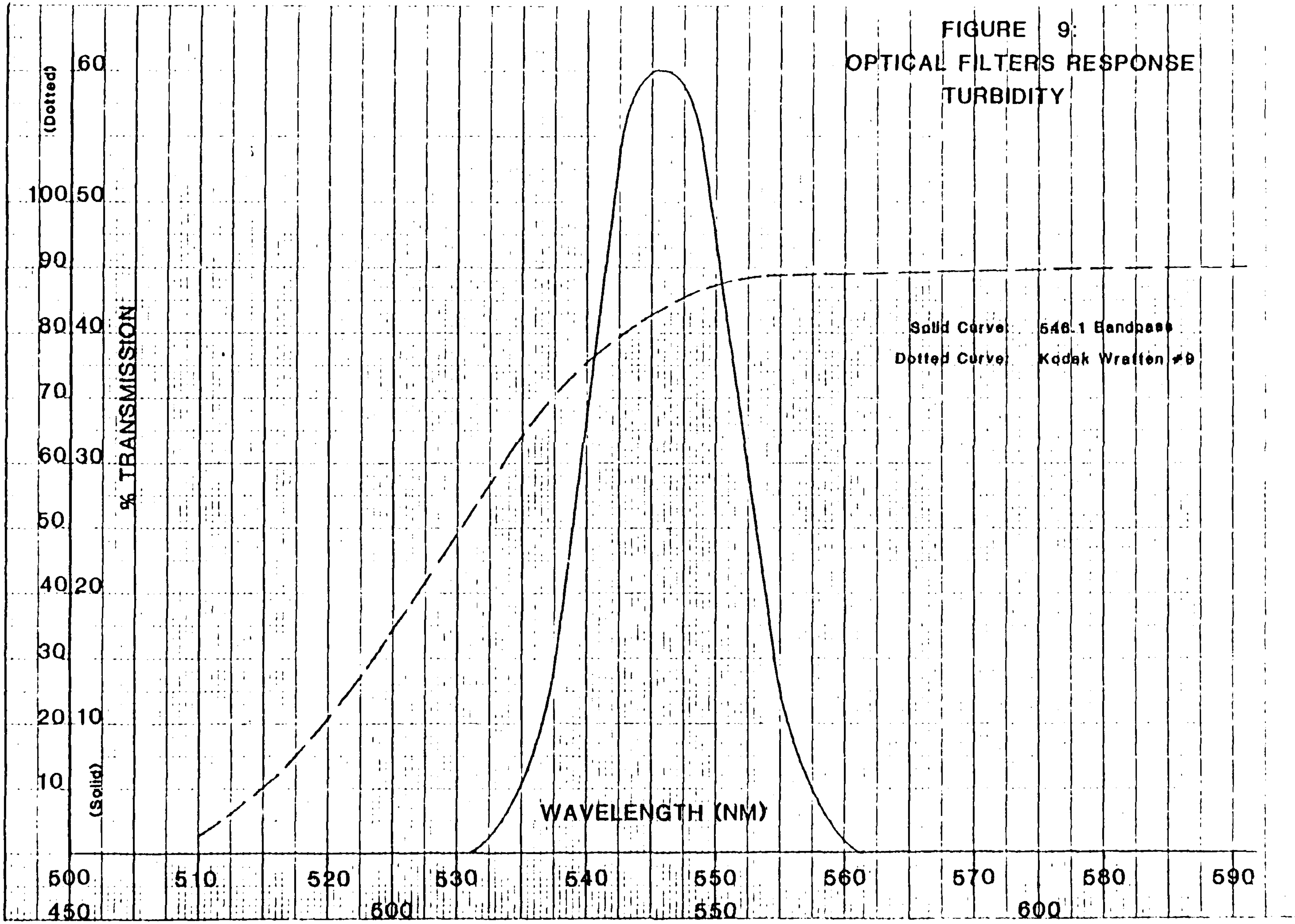


FIGURE 9:
OPTICAL FILTERS RESPONSE
TURBIDITY

signals are applied to two 10.0 KΩ input resistors. The amplifier output is then a direct sum of these two signals. The gain for each signal is unity. The diode configuration on the output is needed to limit the saturation voltage to approximately 10V to prohibit overdriving the data multiplexer system.

3.3 pH Measurement

This measurement is accomplished by using a Broadley-James pH probe mounted externally to the pressure vessel of the Underwater Instrumentation Package and conditioned by circuitry to provide a zero to ten volt signal equal to a pH level of zero to fourteen.

3.3.1 Sensor Specifications

This probe, similar to a Broadley-James Model 9027 probe except in the packaging, is a dual electrode probe with a reference electrode and a measuring electrode integral to a single stem. It is sealed and requires no maintenance other then periodic cleaning. The probe has a pH range from 0 - 14, a temperature range of -5°C to 100°C, and a pressure range to 150 psi.

3.3.2 Circuit Description
(Refer to Drawing 5166-0231)

The pH probe generates a small voltage output with a change in pH levels. The input impedance of the conditioning amplifier must be high. The pH probe conditioning circuitry is located on the circuit board 5166-0231. This circuitry provides gain, offset control, and filtering. The pH probe voltage is connected to the isolation amplifier U1. U1 output is coupled to an instrumentation amplifier (contained in U2), amplified, and then fed to a buffer amplifier which incorporates fine gain and output offset adjustments. The final output stage is a 10 Hz low pass filter.

The following procedure is used to adjust the pH conditioning electronics:

(1) Disconnect J4 (pH Probe).
(2) Adjust R17 to its mid-position.
(3) Connect U2-12 and U2-15 to common (U2-28).
(4) Turn power on.
(5) With a voltmeter connected between Pin U2-3 and common, adjust R16 for 0 volts ±.01V.
(6) Connect U2-2 to common.
(7) With the meter connected between Pin U2-1 and common, adjust R22 for 0 volts ±.01V.

(8) Move the meter lead from U2-1 to U2-7, and adjust R21 for 0 volts $\pm$.01V.

(9) Move the meter lead from U2-7 to U2-20, and adjust R15 for 10 volts $\pm$.01V.

(10) Remove connections from U2-12 and U2-15.

(11) Reconnect J4 (pH Probe).

(12) Connect meter from U2-7 to common.

(13) Immerse pH probe into a 4 pH solution.

(14) Adjust R22 for +2.857 volts $\pm$.01V.

(15) Change pH solution to 10 pH.

(16) Adjust R17 for +7.143 volts $\pm$.01V.

(17) Repeat steps 13 thru 16 until required parameters are obtained.

PH Probe Calibration Parameters:

PH Level	U1 (Input)	U2-7 Output
4	+.293V	+3.045V
7	.013V	+5.010V
10	.353V	+7.192V

3.4 Temperature Measurement

The temperature measurement is made using a thermistor probe that protrudes through the pressure vessel into the aft free flooding section of the instrument. The temperature range is 0 to 30°C with a $\pm$0.1°C accuracy.

3.4.1 Sensor Specifications

The sensor used is a Yellow Springs Instrument Co. Model 710 stainless steel probe. It has a pipe fitting for threading into the pressure vessel and can withstand 500 psi. The probe has a linear response over a temperature range of -30°C to +100°C. The interchangeability of probes is within $\pm$.15°C. The time constant of the probe is 3.6 sec.

3.4.2 Circuit Description
(Refer to Drawing 5166-0151)

The temperature probe conditioning circuitry is located on the Temp/Depth circuit board 5166-0151 and consists of a thermistor bridge, instrumentation amplifier, buffer amplifier, and active filter.

The thermistor bridge configuration consists of R3-R7 along with two thermistors external to the board. The bridge output (21.393 mV/^{o}C) is amplified by the instrumentation amplifier and its output is coupled to a buffer amplifier which contains the fine gain trim and output offset adjustments. The final stage is a 10 Hz low pass active filter. The overall gain of the circuit is 15.58.

The following procedure is used to adjust the temperature probe conditioning circuitry:

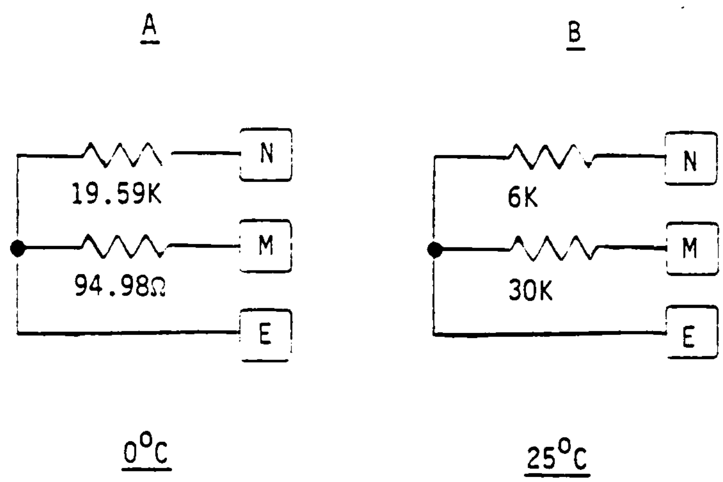
(1) Disconnect J3 (temperature probe).
(2) Place Temp/Depth board on a card extender.
(3) Adjust R9 to its mid-position.
(4) Connect U1-12 and U1-15 to common (U1-28).
(5) Turn power on.
(6) With a voltmeter connected between Pin U1-3 and common, adjust R8 for 0 volts ±.01V.
(7) Connect Pin U1-2 to common.
(8) Move meter connection from U1-3 to U1-1 and common, adjust R14 for 0 volts ±.01V.
(9) Move meter connection from U1-1 to U1-7 and common, adjust R13 for 0 volts ±.01V.
(10) Move meter lead from U1-7 to U1-20 and common, adjust R1 for 4 volts ±.01V.
(11) Remove connection from U2-12 and U2-15 to common.
(12) Connect resistor network A as shown in Figure 10.
(13) Connect meter from U1-7 to common and adjust R4 for 0 volts ±.01V.
(14) Change resistor network to B in Figure 10 and adjust R9 for 8.333 volts.
(15) Repeat steps 12-14 until required parameters are obtained.
(16) Reconnect J3.
(17) Lower temperature of probe to 0^{o}C and adjust R4 for 0 volts ± .01.
(18) Raise temperature of probe to 30^{o}C and adjust R9 for 10 volts ± .01.
(19) Repeat steps 17-19 until required parameters are met.

3.5 Depth Measurement

The depth measurement is obtained by using a pressure transducer that is mounted internal to the pressure vessel and vented into the aft free flooding area of the instrument. The measurement range is 0 to 100 meters with a 0.1 meter accuracy.

Figure 10

Resistor Calibration Networks



3.5.1 Sensor Specifications

The pressure transducer is a Sensotec TJE Series transducer with an overall accuracy of ±.1% of full scale. The transducer measures absolute pressure with full scale equal to 150 psi. It also has a 50% pressure overrange capability.

The measuring port has a stainless steel diaphragm which connects to a foil strain gauge bridge. The bridge excitation is 10 VDC with an output of 3 mV/V. A pressure of 100 psi produces a 30 mV signal.

3.5.2 Circuit Description
(Refer to Drawing 5166-0151)

The depth transducer conditioning circuitry is contained on the Temp/Depth board 5166-0151 and consists of an instrumentation amplifier, buffer amplifier, and output filter.

The instrumentation amplifier input voltage range is 2.204 mV to 24.049 mV which corresponds to a depth of 0 to 100 meters respectively. This amplifier has a gain of 457.7. The instrumentation amplifier output is coupled to a buffer amplifier which incorporates a fine gain trim and output offset adjustments.

The final stage is a 10 Hz low pass active filter. The following procedure is used to adjust the depth transducer conditioning circuitry.

(1) Disconnect J5 (Depth Transducer).
(2) Place Temp/Depth board on a card extender.
(3) Adjust R17 to its mid-position.
(4) Connect U2-12 and U2-15 to common (U2-28).
(5) Turn power on.
(6) With meter connected between Pin U2-1 and common, adjust R16 for 0 volts ±.01V.
(7) Connect Pin U2-2 to common.
(8) With meter connected between Pin U2-1 and common, adjust R22 for 0 volts ±.01V.
(9) Move meter lead from U2-1 to U2-7, and adjust R21 for 0 volts ±.01V.
(10) Move meter lead from U2-7 to U2-20, and adjust R15 for 0 volts ±.01V.
(11) Remove connection from U2-12 and U2-15.
(12) Turn power off.
(13) Connect power supply (+) to U2-12 and (-) to U2-15.
(14) Turn power on.
(15) Set power supply to 2.204 mV.
(16) Connect meter from U2-7 to common.
(17) Adjust R22 for 0 volts ±.01V.
(18) Set power supply output to 24.049 mV.
(19) Adjust R17 for 10 volts ±.01V.
(20) Repeat steps 15-19 until required parameters are obtained.
(21) Turn power off.
(22) Remove power supply from U2-12 and U2-15.
(23) Reconnect J5.
(24) Connect a pressure test unit to the transducer.
(25) Turn power on.
(26) Set pressure to 1.0 psi.
(27) Adjust R22 for meter reading of 0 ±.01V.
(28) Change pressure from 1.0 psi to 145.67 psi.
(29) Adjust R17 for a meter reading of 10 ±.01V.
(30) Repeat steps 26-29 until required parameters are obtained.

3.6 Data Acquisition

The data acquisition subsystem contains a microprocessor controlled analog data multiplexer, 12 bit analog to digital converter, and a digital multiplexer with an asynchronous serial data transmitter. The system is capable of multiplexing 16 channels of data plus 8 status bits and receiving and decoding 8 control bits. It is configured to sample six data channels at a 60 Hz rate. The number of channels and the sampling rate can easily be changed with software modifications.

3.6.1 Analog to Digital Converter (Refer to Drawing 5154-0121)

The analog to digital (A/D) converter consists of two modules: a 16 channel analog multiplexer (U1) and a 12 bit A/D converter (U2). The multiplexer can either be configured to handle 8 channels of differential inputs or 16 channels of single ended inputs. In this system it is configured single ended. The multiplexer will handle bi-polar signals to a maximum of $\pm$10 volts. The A/D converter module (U2) is configured to convert the analog signal from the multiplexer over the full range of $\pm$10V, producing a 12 bit digital word. The addressing for the multiplexer and the control for the A/D converter comes from the multiplexer control board. The multiplexer module and A/D converter are a two component system produced by Analog Devices.

3.6.2 Multiplexer Control Circuitry (Refer to Drawing 5154-0141)

The multiplexer control circuitry controls the analog multiplexer and A/D converter. Its function is to obtain the 12 bit data word from the A/D converter, configure it into a serial data word, and transmit it to the control unit. This circuitry is composed of 5 basic components: a microprocessor (U12), interrupt timing and control (U17, U9), status and control bits (U13), Universal Asynchronous Receiver and Transmitter (UART) (U14), and the A/D interface (U16, U5).

The microprocessor is an Intel 8748 that has an 8 bit CPU and PROM contained in one integrated circuit. The control software for the Underwater Instrumentation Package is stored in this PROM. The microprocessor is interrupt driven. Every 17.5 ms an interrupt occurs which causes the processor to sample each sensor and transmit the data via the data up link to the control unit.

The interrupt timing and contol circuitry contains a programmable timer (U17) which generates the 17.5 ms interrupt pulse. This is routed through the control circuit (U9) which,in the case of multiple interrupts, determines the order of processing. Two interrupts are used

in this instrument: sampling and data received. The data received occurs when data is sent from the Shipboard Control Unit (SCU) via the data down link.

The status and control bits are handled in U13. The control bits are sent to U13 by the microprocessor as an eight bit word and are stored in U13. The status bits are also connected to U13 and sampled as eight bit words by the microprocessor.

The UART is controlled by the microprocessor. This circuitry takes the parallel data from the microprocessor and converts it to a serial data stream transmitting it through the line driver (U3) to the SCU. This circuit also accepts serial data from the control unit through a line receiver (U4) and converts it to parallel data to be used by the microprocessor.

The A/D interface consists of a digital interface which accepts the 4 most significant bits of the conversion (U16) and supplies the address for the analog multiplexer. The data is transferred to and from U16 by the microprocessor. The remaining eight bits of the data are connected directly to a parallel input of the microprocessor.

The basic operational sequence of this section is as follows: Each sensor is sampled and coverted to a 12 bit digital word and stored in the microprocessor memory until all sensors have been sampled. When the sampling is complete, the processor switches to the data transmit mode. In this mode, it transmits the data serially in eight bit bytes to the control unit. In addition to the sensor data words, a sync word and a status word are also transmitted. Table 1 is the a format for the transmission of each block of data every 17.5 ms.

Table 1 - Uplink Data Format

FUNCTION	#8 BIT BYTES
Sync word	2
Sensor 1	2
Sensor 2	2
Sensor 3	2
Sensor 4	2
Sensor 5	2
Sensor 6	2
Status word	1

The data format for each sensor is identical. Bits 0 thru 11 are data, 12 thru 15 zeros. The sync word is all ones. The status word is all data.

3.7 Power System

The power supplied to the instrument is a constant current of 1.5A with a minimum voltage required at the instrument of 50 volts DC. The internal regulators in the instrument then derive the required voltages for all the instrumentation.

3.7.1 Basic Power System.

(Refer to Drawings 5166-0101 and 5166-0191)

As shown in drawing 5166-0101, a block labeled Regulator No. 3 contains the zener diodes that regulate the constant current from the control unit to plus and minus 20 volts to supply the remaining regulators. The center point of the zener regulator then becomes the 0 volt reference for all circuitry internal to the Underwater Instrumentation Package. This zero point reference is not connected to the housing, thus isolating the unit from sea water. There is no return connection of this point to the control unit. The input to the zeners, approximately 50V, is floating and not referenced to the control unit ground or sea water. This condition is necessary to generate the plus and minus voltage with respect to the center point of the zener regulator.

The main voltages used by the instrumentation are plus and minus 15 volts and plus 5 volts. These voltages are generated by three integrated circuit regulators located on voltage regulator assembly #2 (5166-0191). These are fixed voltage regulators with a current capability of 1.0A.

3.7.2 Lamp Power Supplies

(Refer to Drawings 5166-0181 and 5166-0201)

There are two power supplies associated with the lamp power. Both supplies are Venus Scientific DC to DC converters.

The low voltage supply, a Venus F6, produces 600 VDC at 16 mA with an input voltage of 25 to 31 VDC at 630 mA. This supply is controllable with a DC voltage which enables it to be used with the lamp intensity control circuit. This supply receives its input from a regulator (U2) located on the voltage regulator assembly #1 (5166-0181). As shown in drawing 5166-0201, the 600V supply is connected through an isolation diode network of CR1, CR2,CR3 and a 20K Ω resistor which sets the lamp operating current.

The second supply for the lamp is a Venus K30 which provides a maximum output of 3,000 volts at .5 mA. The output of this supply is controlled by the DC input. Varying the input from 3V to 15V will vary the output from 600V to maximum. The input for this supply is generated by a variable regulator (U1) on voltage regulator assembly #1.

The two supplies are combined to power the lamp. The circuitry necessary to achieve this is located on the photomultiplier and HV power supply assembly (5166-0201). The negative outputs of the supplies are connected and go to the lamp through a 240 Ω, lamp current measuring resistor. The positive output of the K30 supply is connected to the lamp through a diode (CR4) and a 6.2 MΩ resistor. The diode provides isolation from the 600V supply and the resistor is to limit the current.

3.7.3 Photo Multiplier Tube Power Supply
(Refer to Drawing 5166-0201)

The PMT power supply is a Venus K15 high voltage DC/DC converter with a maximum output of 1500 volts DC at 1.0 mA. The output is adjusted by varying the DC input from 3 to 15 volts, which changes the output from 300 to 1500 volts. This supply is located on the photo multiplier and HV. power supply assembly (5166-0201) and receives its input from a variable voltage regulator (U3) on the voltage regulator assembly 5166-0181.

3.7.4 Wet Sensor
(Refer to Drawing 5166-0171)

The purpose of the Wet Sensor is to detect moisture in the instrument and send a signal to the control unit. This circuit is located on the auxiliary electronics board (5166-0171) and consists of a voltage comparator with probes connected to the inputs. A decrease in resistance between the probes causes the output of the comparator to change from 0 VDC to +5 VDC.

3.8.0 Mechanical
(Refer to Drawing 5166-0100)

3.8.1. General

The overall length from nose piece to stabilizing ring is 47.5". The pressure vessel that houses the optics and instrumentation is made of aluminum pipe 8.5" in diameter and 25.0" long. It has removable end caps with "O" ring seals.

The front nose piece, which acts as an inlet for the water, also contains an underwater connector and ballast weights. It is shaped to reduce the drag of the instrument.

The rear cone, which is free flooding, has a flow tube through the center for the outlet of the water forced through the instrument. This area also contains the wet ends of the temperature, pH, and depth

sensors. Water scoops on the side along with vents allow a slow change in the water in this cavity. This causes a slower response for these sensors but will protect them from physical damage and also turbulent flow which could disturb the measurements. An access plate is provided to allow calibration of these sensors and installation of a protective cap on the pH probe.

The instrument has two hydrodynamic depressing fins and one vertical fin surrounded by a stablizing ring.

The internal configuration consists of a center flow tube with optics blocks for fluorescence, absorption, and turbidity measurements. Helical light baffles are inserted in the flow tubes to prevent ambient light from entering the instrument. The instrumentation is mounted on an assembly around the flow tubes. This assembly is removable intact with the rear pressure vessel end cap.

3.8.2 Towing and Ballasting

The instrument is towed from a single point located 19.75" aft of the tip of the nose piece. A maximum of 45 lbs. of ballast weight can be secured in the nose piece. When all the ballast is in place, the instrument will enter the water nose down. Due to the positioning of gravity and the tow point, the force of the water striking the fins and stabilizing ring will bring the instrument horizontal at a moderate towing speed (4 knots). This feature provides for optimum flow of water through the instrument. In operations involving very low towing speeds (2 knots or less) and shallow depths, the ballast weights may be trimmed to improve tracking response. This would also reduce the overall weight and make handling easier.

3.8.3 Pressure Vessel

The pressure vessel is an aluminum pipe with two removable end caps with "O" ring seals. The joints connecting the flow tubes to the bulkheads and optics blocks are "O" ring seals as is the pH housing and the electrical connector. The temperature probe and depth sensor use pipe thread seals.

This system is designed to withstand pressures to 150 psi; the limiting factor at this point is the pH probe. This unit has been tested in a hydrostatic pressure chamber for a duration of 4 hours at 150 psi.

4.0 Shipboard Control Unit (Refer to Figure 3)

The Shipboard Control Unit (SCU) is used to decode the data from the towed instrument and provide a real time display. This unit

generates control functions and provides the power to the underwater unit.

As seen in Figure 3, the data controller receives serial data from the Underwater Instrumentation Package and provides a reconstructed 12 bit data word for each sensor. A 12 bit digital to analog (D/A) converter provides a DC output voltage for analog recording.

The output of the D/A converter is connected to six sample and hold buffer circuits controlled by the data controller. This provides continuous simultaneous display of all sensors. The sensor information is continuously displayed on a front panel digital display. Control switches generate a control word through the data controller which is transmitted via the data down link to change functions in the Underwater Instrumentation Package. The power for the instrument is generated by a 1.5A constant current supply.

4.1 Controls

The control switches necessary for operating the SCU and the UIP are located on the front panel of this unit. The following is a functional description of each control:

Control Unit Power: Controls the power to the SCU only.

Sensor Power: Connects the 1.5A constant current power source to the instrument cable.

Alarm On/Off: Enables the alarm that indicates data error or wet sensor on.

Alarm Reset: Resets circuitry that triggers the alarm; if error signal is not present will turn alarm off.

Reset: General reset for all circuitry in the SCU.

Lamp Polarity SW: Not Used.

Lamp Polarity Indicator: Not Used

Lamp Start: This switch is actuated to turn the lamp on; the bottom half of the switch lights, indicating that the lamp HV Power Supply is energized. The top half of the switch lights when the lamp is energized and drawing current.

Auto Zero /Fixed Reference: Not used.

Initiate: Used to turn-off lamp High Voltage Power Supply after lamp is energized.

Constant Volts/Loop: This switch selects the mode of operation of the light source in the instrument. Top half of switch indicates constant volts, bottom, Loop Control.

Wet Sensor/Data Error: Indicates either a detection of moisture in the instrument or a loss of data from the instrument.

4.2 Display/External Monitor

The display consists of six individual digital readouts: one for each sensor. All the displays are 3 1/2 digits; maximum value displayed is 1999. The temperature, depth, and pH displays readout in engineering units. The depth range is from 0.0 to 100.0 meters. The temperature range is from 0.0 to 30.0°C. The pH range is from 0.0 to 14.0. The absorption, fluorescence, and turbidity display voltage range is from -10.00 volts to +10.00 volts.

Located on the rear panel of the unit are BNC connectors for each sensor. These provide DC voltages for external recording. The voltage range for depth, temperature, and pH is 0 to +10.0 volts for full range of the sensor. The fluorescence, absorption, and turbidity will be the same value as displayed on the digital display: ±10.0 volts. The fluorescence and absorption signals at this point will go to a more negative voltage with an increase in signal levels; i.e., -10.0 volts equals maximum signal levels. The turbidity will go in the positive direction for increase in signal; i.e., +10.0 volts equals maximum signal level.

4.3 Circuit Description

4.3.1 Demultiplexer
(Refer to Drawing 5166-0331)

The Demultiplexer section consists of two circuit boards in the unit and is basically the same as the multiplexer circuitry in the UIP.

The demultiplexer is an interrupt driven microprocessor system. The serial data stream from the UIP is reassembled by the microprocessor into a 12 bit data word. This data word is converted to an analog voltage via the D/A converter. This conversion is done for each sensor; a control pulse is generated along with the conversion that latches the

DC voltage into sample and hold circuits for each sensor channel. The status word that is generated by the instrument is also decoded into control bits to drive the indicators. Switch functions are stored by this circuit and are transmitted to the UIP at the appropriate time, between data transmissions from the UIP.

The demultiplexer circuitry has six basic subsections: microprocessor, control decoding, universal asynchronous receiver transmitter (UART), status word control, switch control, and the D/A converter.

The microprocessor (U20) is the same as that used in the multiplexer except for a different program. The interrupt for this section is generated by the UART for data received. Each byte of data generates an interrupt. The data from the UART is taken by the microprocessor and routed to the appropriate outputs. A second interrupt is generated when a switch function is changed. At this time the microprocessor takes the data from the switch control and routes it to the UART which in turn transmits the data to the UIP via the data down link.

The control decoding consists of circuits U24, U25, U39, and U40. The microprocessor sends a control word to these circuits which in turn decode the word into control signals. U24 and U25 generate signals used within the demultiplexer, while U30, U39, and U40 decode the signals that control the sample and hold circuits, of which a maximum of 16 can be controlled.

The UART controls the transmitting and receiving of data. It receives serial data through the line receiver (U42) and converts the data to a parallel 8-bit word for use by the microprocessor. The reverse is true for transmitting data. Eight bit parallel data is taken in and converted to serial data and transmitted by the line driver (U36) to the instrument package.

The status word control receives its data as an 8-bit word from the microprocessor, latches the data in U21, and drives the indicator lamps with U22.

The switch control consists of U31, U34, U35, and U41. Switch conditions are latched by U34 and U35. U31 is used to interface this data to the microprocessor.

The D/A converter consists of U37, U38 and the D/A converter (U52). The purpose of U37 and U38 is to receive the data from the microprocessor in two separate data transfers: one 8-bit byte and one 4-bit byte. These circuits then present a composite 12 bit word to the D/A converter.

4.3.2 Sample and Hold Circuit
(Refer to Drawing 5166-0320)

The sample and hold circuit is a separate board (5166-0320) which contains 8 channels. One DC input from the D/A converter is common to all the channels. There are 8 control lines that are pulsed to latch the voltage into the appropriate channel. The sample and hold circuits are buffered by an additional operational amplifier to drive external recording equipment.

4.3.3 Digital Display
(Refer to Drawing 5166-0311)

This section consists of a display which has six 3 1/2 digit LED displays. The displays have a built-in latch which holds the data between updates. The other section is an A/D converter card (5166-0311) which contains DC scaling amplifiers, a 12-bit A/D Binary Coded Decimal (BCD) converter, and control circuitry.

The inputs to this circuit are the outputs of the sample and hold circuits. The input scaling amplifiers convert the DC voltages to a voltage range that can be converted and displayed as engineering units. The control circuitry and the A/D converter continuously sample the scaling amplifier, convert the voltage to 3 1/2 digit BCD data word, and latch the data into the appropriate display.

The operation of this circuit can be explained by referring to Drawing 5166-0311. The input scaling amplifiers (U1 through U3) are routed to the A/D converter (U6) by analog FET switches that are controlled by a shift register (U13) which also enables the strobe gates (U7 and U8). The position of the bit in the shift register determines the channel being converted. U33 determines the sample time. At the end of each conversion, the shift register is incremented. U14 through U16 latch the polarity information and the data for the most significant display digit.

The following procedure is used to adjust the display circuitry:

(1) Remove U4 and U5.
(2) Place a power supply across R33 and set to 199.85 mV; adjust R36 until depth display is switching from 199.8 to 199.9.
(3) Apply 0.00 mV across R33 and adjust R37 for 0.0V.
(4) Repeat steps (2) and (3) until required parameters are obtained.
(5) Remove power supply from R33.
(6) Replace U4, U5.

(7) Apply 10V to the input of all six channels; adjust R14 for a 100.0 reading on depth, R16 for a reading of 10.0 on fluorescence, R18 for a reading of 30.0 on temperature, R20 for a reading of 10.0 on absorption, R22 for a reading of 14.0 of pH, and R24 for a reading of 10.0 on turbidity.

4.4 Operational Procedure

Operation of the SCU and the UIP is straight forward. The following procedure should be used:

(1) Turn power On to the SCU.
(2) Initiate the RESET Switch. The displays will indicate meaningless data.
(3) Turn Power ON to the UIP. The temperature, pH, and depth should indicate real data. The fluorescence, absorption, and turbidity will be meaningless. The Lamp ON indicator and High Voltage ON indicator should NOT be illuminated.
(4) If the Constant Volts/Loop indicates constant volts, select loop.
(5) Depress the Lamp START switch.
The High Voltage ON indicator should be ON. The Constant Volts indicator should be ON.
(6) When the Lamp ON indicator comes ON, depress the Initiate switch. The following should occur:
High Voltage indicator OFF
Constant Volts indicator OFF
The Loop indicator ON
Lamp indicator ON
(7) If the Lamp fails to remain on, initiate RESET and repeat the sequence.
(8) If the UIP is in the water or the flow tube is filled with water, the fluorescence, absorption, and turbidity readings should be close to zero volts.

5. System Calibration

5.1 Fluorescence and Absorption

The calibration of the fluorescence and absorption measurement is based on a background level produced by deionized water. The background level is then assumed to be interfering signals caused by coupling of the light source to the detector. This background is electrically surpressed in the conditioning circuitry. Standard samples of different concentrations of chemicals are then poured into the instrument and a voltage is recorded for that concentration.

5.1.1 Standard Sample

A standard solution is prepared using commercial grade chemicals (Figure 11). The initial solution is a concentration of 10^{-3} and is prepared as shown in Figure 12. These solutions are kept refrigerated until used. The standard solution is then diluted with deionized water to achieve the desired concentrations for calibration.

5.1.2 Calibration Procedure:

(1) Rinse the UIP flow tube with alcohol.
(2) Flush several times with deionized water to remove the alcohol.
(3) Fill with deionized water. Observe the reading on the fluorescence and absorption displays. If the readings are not close to zero volts, an adjustment of the zero suppression must be made. Step 4.
(4) Adjustments are found on circuit board 5166-0211. The absorption adjustments are R32 (coarse) and R12 (vernier). The fluorescence adjustments are R33 (coarse) and R13 (vernier). Adjust the venier controls to zero the display. If the vernier has no effect on the display, turn the vernier full counterclockwise and adjust the coarse to bring the display close to zero. Fine adjust with the vernier.
(5) Starting with the lowest concentration of the calibration solution, fill the instrument and record the readings.
(6) After the final reading, flush the instrument with deionized water and re-check the zero point.
(7) Caution should be taken to avoid creating bubbles when filling the instrument with solutions - the bubbles will cause scattering in the measuring chamber resulting in false levels.

5.1.3 Data

The calibration of the instrument to date has been done with anthracene. The anthracene calibration curve (Figure 13), shows a sensitivity of 10^{-9} which is equivalent to the sensitivity desired. The oils measured (Figure 14) have a sensitivity of parts in 10^{-7} which is two orders of magnitude less sensitive than previously measured (Figure 15).

5.2 Turbidity

Solutions that are based on a standard Nephelometric Turbidity Unit (NTU) solution are used for the turbidity calibration. The original intent was to measure the loss of light and also the amount of scattered

Figure 11

CHEMICAL SAMPLES

Chemical	Supplier	Lot #	
Anthracene	Eastman 480	B7H	Solid
AS-007-CDO (Crude)	Coast Guard R&D		
Benzene	Eastman 13012	D4C	Liquid
Chrysene	Eastman 4217	681-1N	Solid
Cumene	Eastman 1481	C7B	Liquid
Diesel oil	APL		
Ethylbenzene	Eastman 719	D8B	Liquid
GE-003-CME (Crude)	Coast Guard R&D		
Heating oil	APL		
Hydroquinone	Eastman 201	C8B	Solid
M-Xylene	Eastman 275	A8X	Liquid
Napthalene	Eastman 168	C4B	Solid
O-Cresol	Eastman P81	A5E	Liquid
P-Cresol	Eastman P449	B7E	Liquid
Phenol	Eastman 201	A8B	Solid
Phthatic Acid	Fisher A-256	731659	Solid
Quinoline	Eastman 218	A8B	Liquid
Styrene	Eastman 1465	B9A	Liquid
Toluene	Eastman 13037	E4A	Liquid
Turpentine	APL		

Figure 12

STANDARD 10^{-3} SOLUTION PREPARATION

Chemical	Mixture (10^{-3})
Anthracene	.1 gm → 100 ML Ethyl Alcohol
AS-007-CDO (Crude)	.1 gm → 100 ML Ethyl Alcohol
Benzene	.1 gm → 100 ML Deionized H_2O
Chrysene	.01 gm → 100 ML Ethyl Alcholol = 10^{-4}
Cumene	.1 gm → 100 ML Ethyl Alcohol
Diesel oil	.1 gm → 100 ML Ethyl Alcohol
Ethylbenzene	.1 gm → 100 ML Ethyl Alcohol
GE-003-CME (Crude)	.1 gm → 100 ML Ethyl Alcohol
Heating oil	.1 gm → 100 ML Ethyl Alcohol
Hydroquinone	.1 gm → 100 ML Deionized H_2O
M-Xylene	.1 gm → 100 ML Ethyl Alcohol
Napthalene	.1 gm → 100 ML Ethyl Alcohol
O-Cresol	.1 gm → 100 ML Ethyl Alcohol
P-Cresol	.1 gm → 100 ML Ethyl Alcohol
Phenol	.1 gm → 100 ML Deionized H_2O
Phthatic Acid	.1 gm → 100 ML Ethyl Alcohol
Quinoline	.1 gm → 100 ML Ethyl Alcohol
Styrene	.1 gm → 100 ML Ethyl Alcohol
Toluene	.1 gm → 100 ML Ethyl Alcohol
Turpentine	.1 gm → 100 ML Ethyl Alcohol

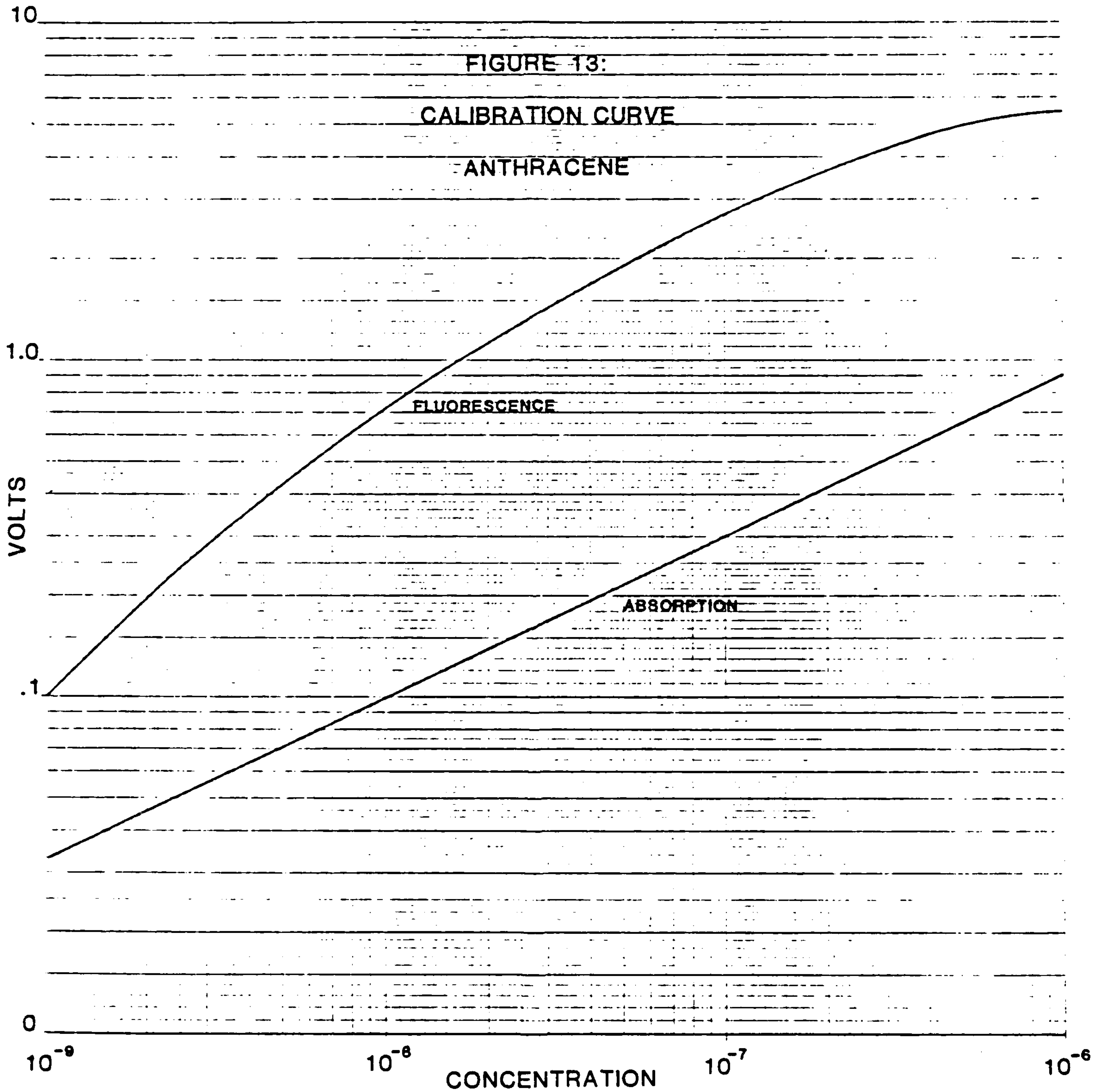


FIGURE 13:
CALIBRATION CURVE
ANTHRACENE
FLUORESCENCE
ABSORPTION
VOLTS
10
1.0
.1
0
10^{-9}
10^{-8}
10^{-7}
10^{-6}
CONCENTRATION

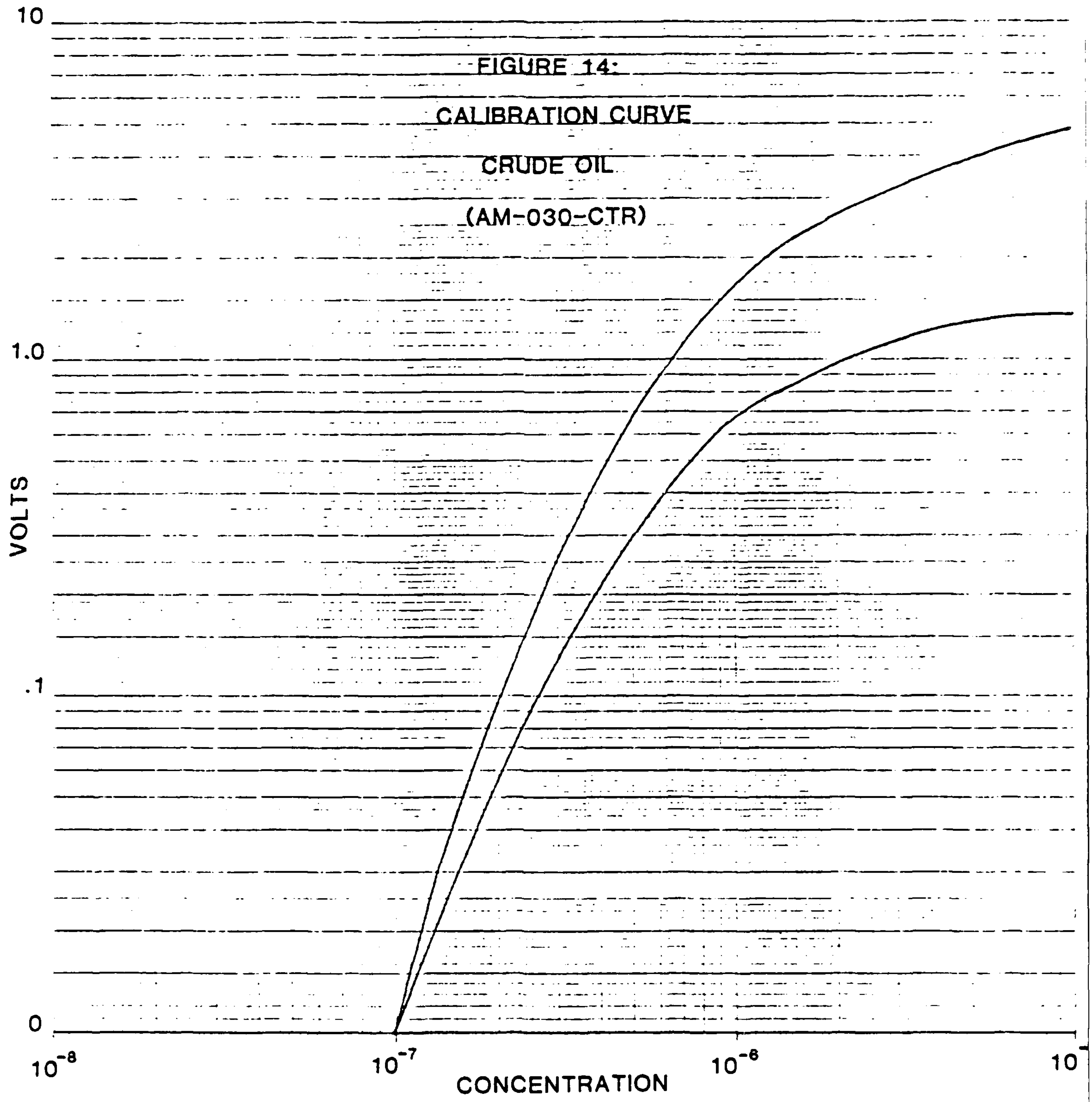


FIGURE 14:
CALIBRATION CURVE
CRUDE OIL
(AM-030-CTR)
VOLTS
10
1.0
.1
0
10^{-8}
10^{-7}
10^{-6}
10
CONCENTRATION

Figure 15

Sensitivity Comparison

		Baird Data		APL Data		APL Absorption Data @253.7 NM	
Chemical	BW10NM λ (NM) Excitation	BW2NM λ (NM) Emission	S/N = 2 Detection Limit (PPM)	Detection Limit (PPM) Deionized H_2O	Detection Limit (PPM) Seawater	Detection Limit (PPM) Deionized H_2O	Detection Limit (PPM) Seawater
Anthracene	355	378	.001	.001	.001	.01	.1
Benzene	250/265	279	2/4	1.0	1.0	1.0	6.0
Chrysene	270	383	.002	.001	.001	.05	.1
Cumene	250	283	3.0	.1	1.0	.1	.1
Ethylbenzene	260/250	283	1.5/3.1	1.0	2.0	10.0	4.0
Hydroquinone	290	326	.025	.01		.05	.02
M-Xylene	270/260	285	1.4/2.0	1.0	1.0	.2	1.0
Napthalene	280	323	.02	.001	.001	.05	.05
O-Cresol	280	293	.04	.006	.05	.3	1.0
P-Cresol	280	299	.03	.006	.01	.5	.5
Phenol	275/265	288	.007/.011	.01	.01	.05	.05
Phthatic Acid	280/340	339	84/97	2.0	2.0	.5	.5
Quinoline	275	321	No Data	.1		.05	
Styrene	270	306	.03	.001	.001	.03	.01
Toluene	215/250	284	1.6/2.1	.3	2.0	1.0	2.0
Turpentine	270/260	283	13/31	6.0	6.0	1.0	1.0
GE-003-CME	-	-	-	.005	.005	.4	.1
Heating oil	-	-	-	.005	.005	.05	.1
AS-007-CDO	-	-	-	.005	.005	.1	.1
Diesel oil	-	-	-	.005	.005	.05	.05

light. Due to lamp stability problems only the scattered light was measured. The turbidity calibration is based on scattered light produced by the standard NTU solutions.

5.2.1 Standard Samples

The standard solution is based on a Formazin polymer used as the turbidity reference suspension. A stock turbidity suspension is the base solution and is prepared as follows:

Solution 1: Dissolve 1.00 g hydrazine sulfate in distilled water and dilute to 100 ml in a volumetric flask.

Solution 2: Dissolve 10.00 g hexamethylenetetramine in distilled water and dilute to 100 ml in a volumetri flask.

In a 100 ml volumetric flask, mix 5.0 ml solution 1 with 5.0 ml solution 2. Allow to stand 24 hours at $15^{\circ}C \pm 3^{\circ}C$ then dilute to the 100 ml mark and mix. This solution is then equal to 400 NTU. Mix solution using the 400 solution and distilled water to produce 40, 4 and 0.4 NTU solutions. The stock solution is good for approximately a month, but the diluted solutions should be remixed every week.

This procedure is used by the Environmental Protection Agency to calibrate Nephelometers for measuring turbidity of drinking water.

5.2.2 Calibration Procedure:

(1) Rinse the UIP flow tube several times with water. Fill with distilled water.

(2) The reading on the turbidity display should be approximately zero. If not zero, readjust zero point (Step 3).

(3) If only the one detector is being used (scattering) - adjust R13 (Vernier) on card 5166-0141 for a zero reading. If the display does not change with R13, turn R13 counterclockwise and adjust R33 (coarse) for near zero reading, then readjust R13 for zero.

If both the scattering and absorption measurements are being used, then the above procedure must be used for both. The adjustments for absorption are R12 (vernier) and R32 (coarse) on the same board.

If both must be adjusted, the output of board 5166-0141 must be monitored when adjusting each (pin A absorption

and pin S scattering). When both are adjusted to zero the display should be zero.

(4) Starting with the 0.4 NTU solution, fill the UIP flow tube and record the display reading. Repeat for each solution.

(5) After the last solution, rinse the UIP flow tube and fill with distilled water to re-check zero point.

NOTE: Before any solutions are used for measurements, they should be well shaken and let stand until the air bubbles are gone. Care should be taken when filling the flow tube with solution; any air bubbles created will cause false readings.

5.2.3 Data

This instrument was calibrated using the calibration procedure over a NTU range of 0.4 to 400. Figure 16 is this calibration curve.

5.3 pH Probe

The pH probe is calibrated at three points: 4, 7, and 10. This gives a good indication of accuracy and linearity.

5.3.1 Standard Samples

The solutions used were prepared using Metrepak P-Hydrion Buffers. The buffers are contained in premeasured capsules and are mixed with 100 ml of the distilled water. The accuracy of the solution is ± 0.02 pH units.

5.3.2 Data

Figure 17 is the calibration curve.

5.4 Temperature

The temperature probe was calibrated using a temperature controlled oil bath; the calibration was done at $0^{\circ}C$, $25^{\circ}C$ and $30^{\circ}C$.

5.4.1 Standard Source

The source was a Guildline Model 9730 Constant Temperature Oil Bath, with a system accuracy of $5m^{\circ}C$.

5.4.2 Data

Figure 18 is the calibration curve.

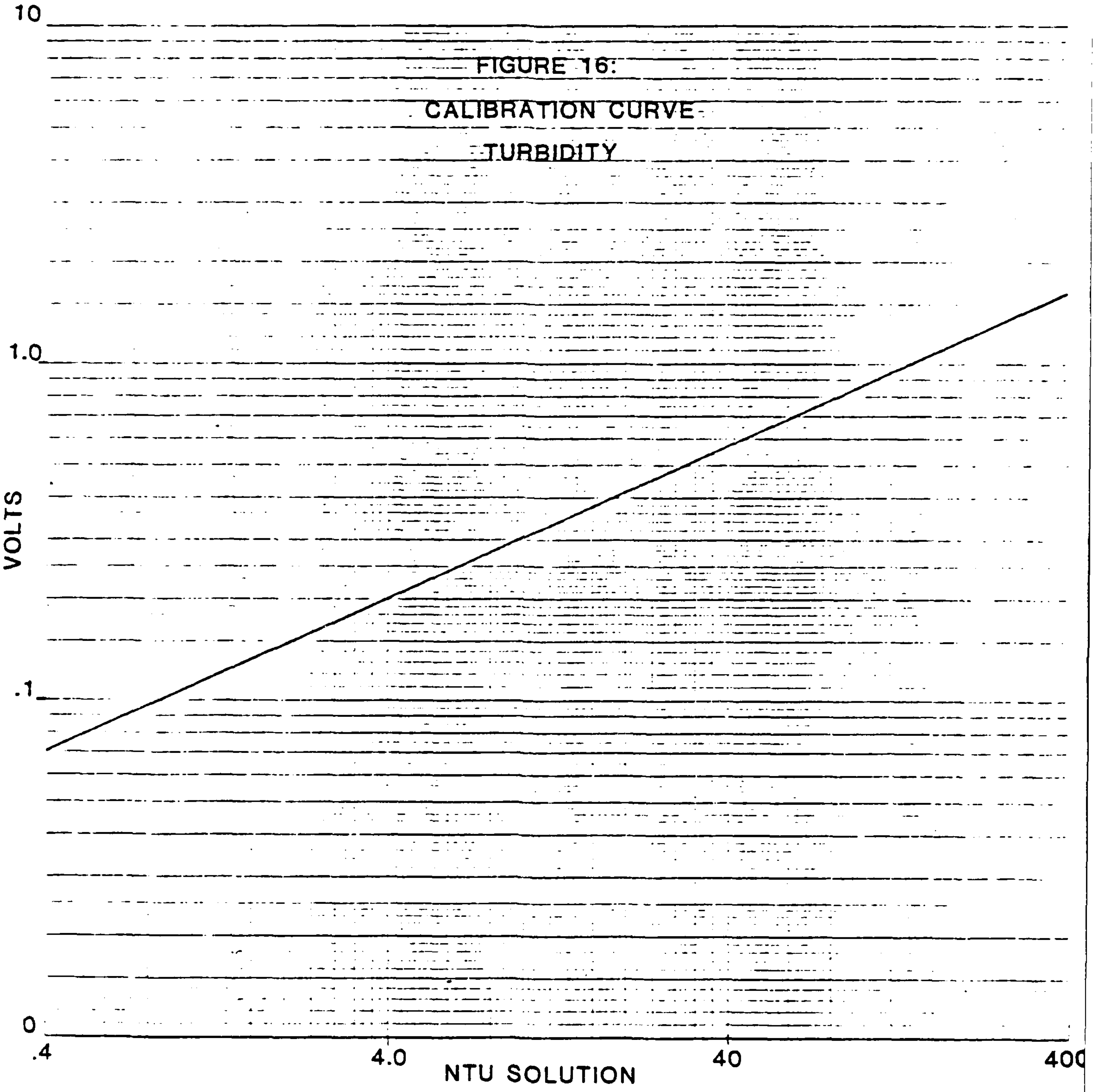


FIGURE 16:
CALIBRATION CURVE
TURBIDITY
VOLTS
10
1.0
.1
0
.4
4.0
40
400
NTU SOLUTION

FIGURE 17:

pH PROBE CALIBRATION

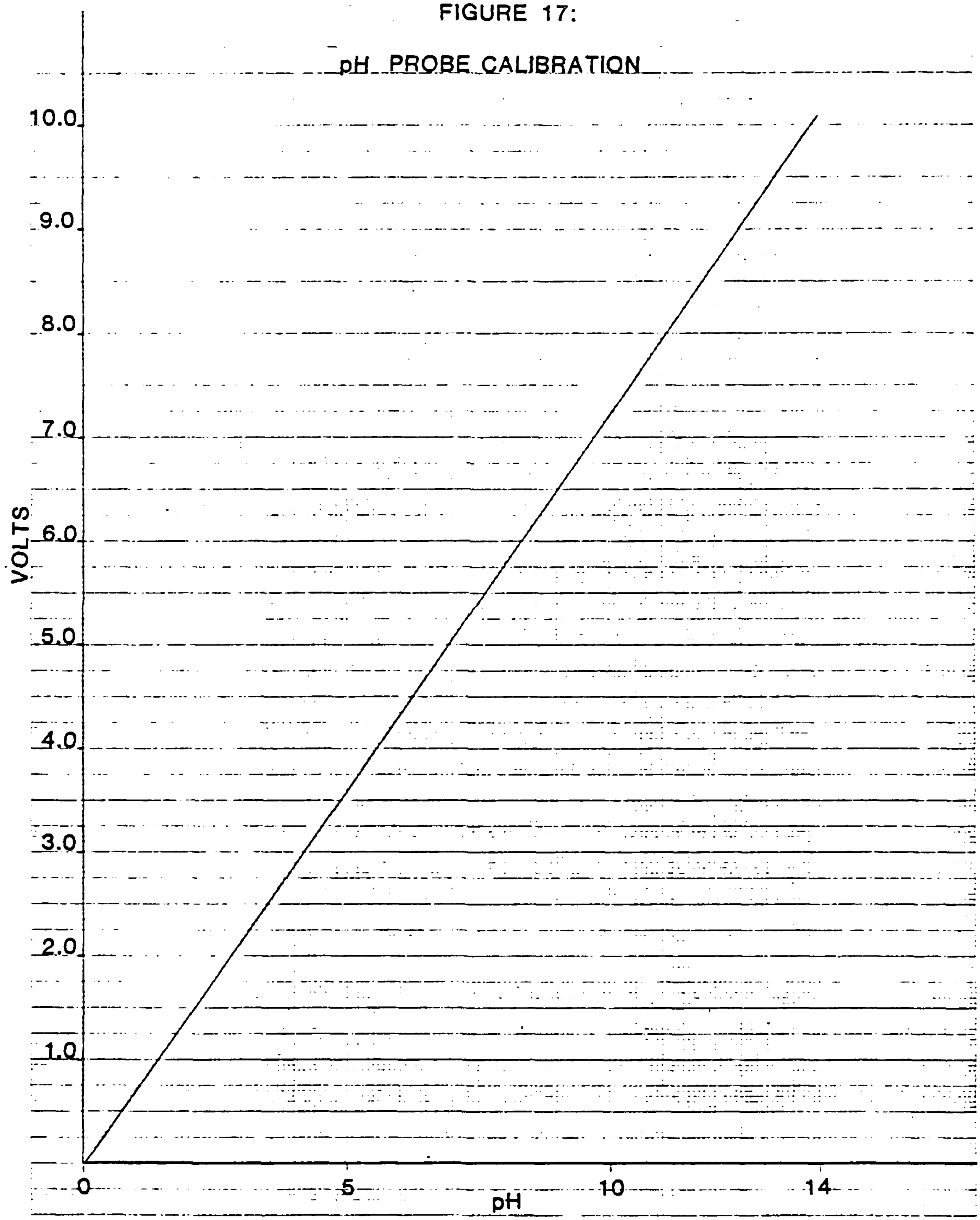
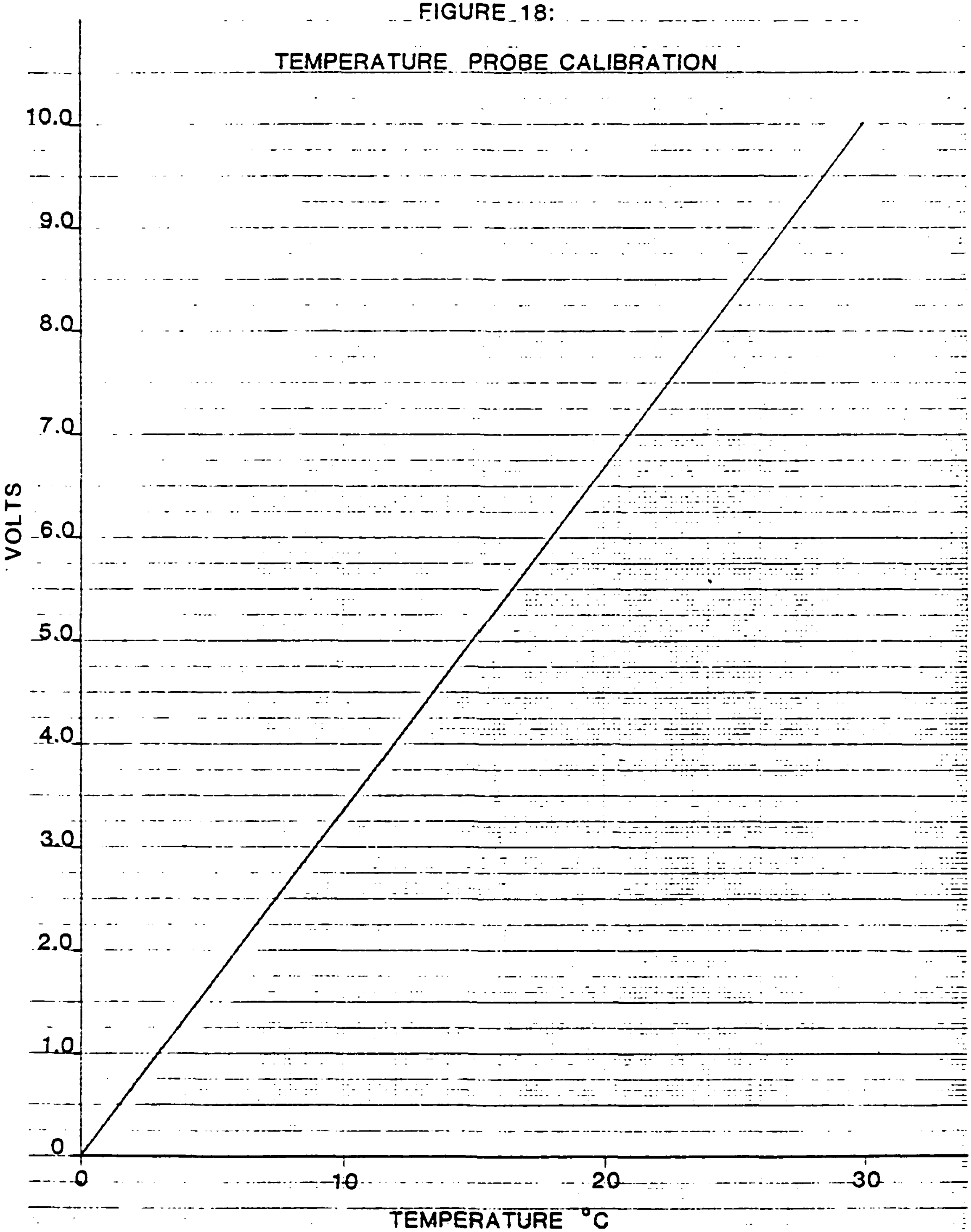


FIGURE 18:

TEMPERATURE PROBE CALIBRATION



5.5 Depth

The depth calibration was done using a standard pressure test source in 20 psi steps to a maximum of 145 psi which is equal to 100 meter depth.

5.5.1 Standard Source

The source used was a Chandler Engineering Co. Model 58-155 Precisions Pressure Standard with a system accuracy of 0.02%.

5.5.2 Data

Figure 19 is the calibration curve.

6.0 System Status

6.1 Sensitivity Comparison

The main objective was to develop an instrument with high sensitivity for the fluorescence and absorption detection. The turbidity sensor has not been specified for sensitivity. The required sensitivity for fluorescence was 1 part per billion. The absorption sensitivity was undefined. Previous laboratory tests using a laboratory set-up equivalent to the detection scheme used in this instrument produced results as shown in Figure 15.

The sensitivity measurement made at APL on the prototype instrument did not include the entire list of chemicals but concentrated on anthracene and crude oil. The sensitivity curve shown in Figure 13. for anthracene compares favorably with the previous data. The oil sensitivity was less, as shown in Figure 15. At this time the decrease in sensitivity is unexplainable. It could possibly be attributed to a high background level in the UIP due to coupling of light from the lamp to the fluorescence detector.

Further investigation is needed to examine the reduced sensitivity and determine the exact cause. One possible solution is to reduce light coupling from the light source to the dectector by installing a lens to focus the light in the measuring chamber.

6.2 Lamp Stability

The lamp used is basically a very stable light source; but due to packaging requirements and available components, the lamp was not operated in its normal mode. The lamp is normally operated from an AC power source. Since the power supplies normally used were too large to package in the instrument, a DC power source was selected.

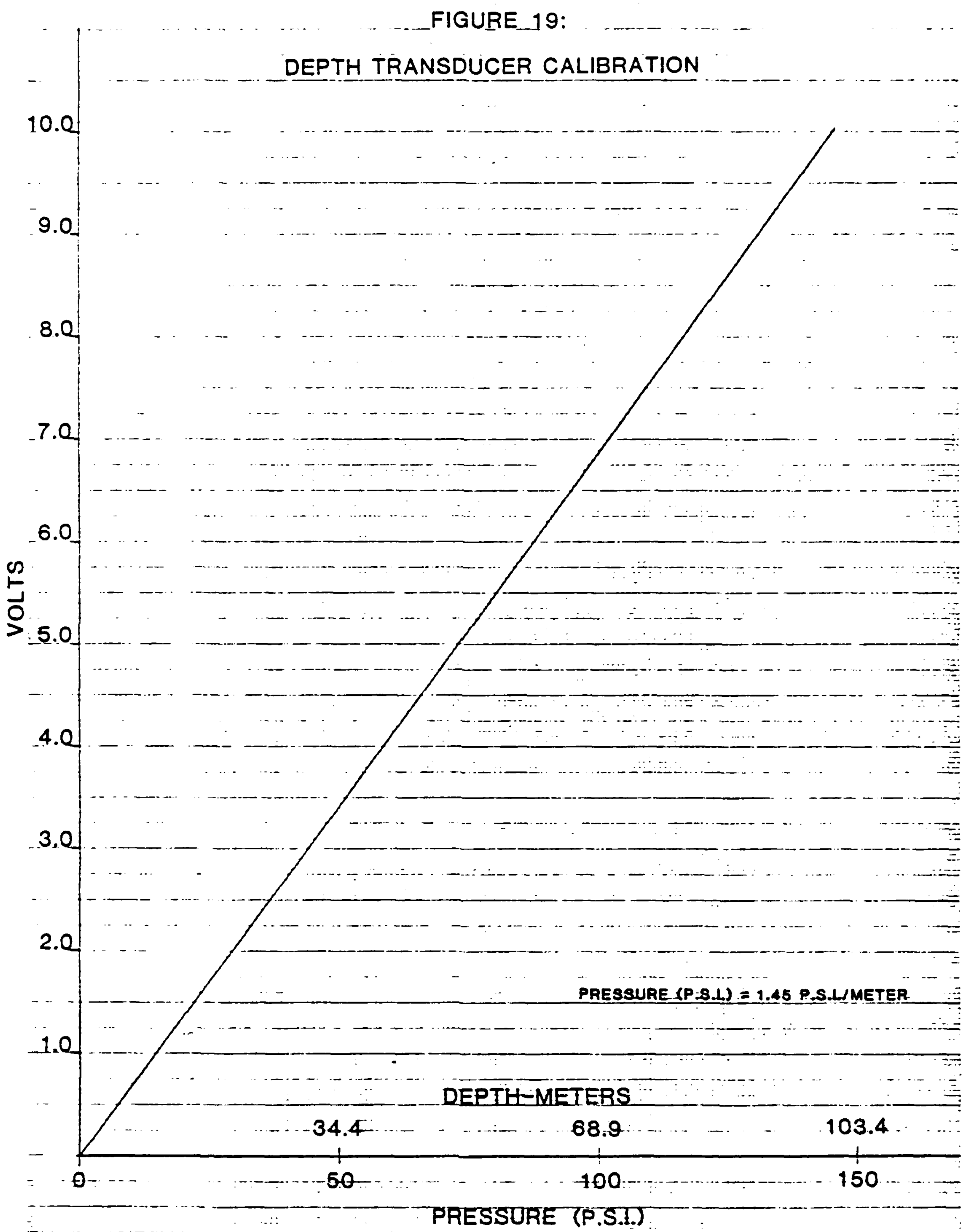


FIGURE 19:
DEPTH TRANSDUCER CALIBRATION
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
VOLTS
PRESSURE (P.S.I.) = 1.45 P.S.I./METER
DEPTH-METERS
34.4
68.9
103.4
0
50
100
150
PRESSURE (P.S.I.)

The operation of the lamp using DC power is acceptable according to the manufacturer, but limitations exist. Migrating of the mercury to one electrode reduces the lifetime of the lamp. This also can cause a shift in the spectrum and reduced light output. The change in lamp performance has been noted in the instrument and causes drift resulting in unstable zero reference levels.

Further investigation is needed to determine the feasability of designing an AC power source.

6.3 Conclusions

The towed fluorometer hardware developed by APL per the first year final report for the Coast Guard R & D Center (APL memorandum EEO-80-4) has met the specifications outlined by the Coast Guard R & D Center. As outlined in this report, areas exist for design improvement within the UIP. The system has undergone laboratory test at APL under the supervision of the Coast Guard sponsor.

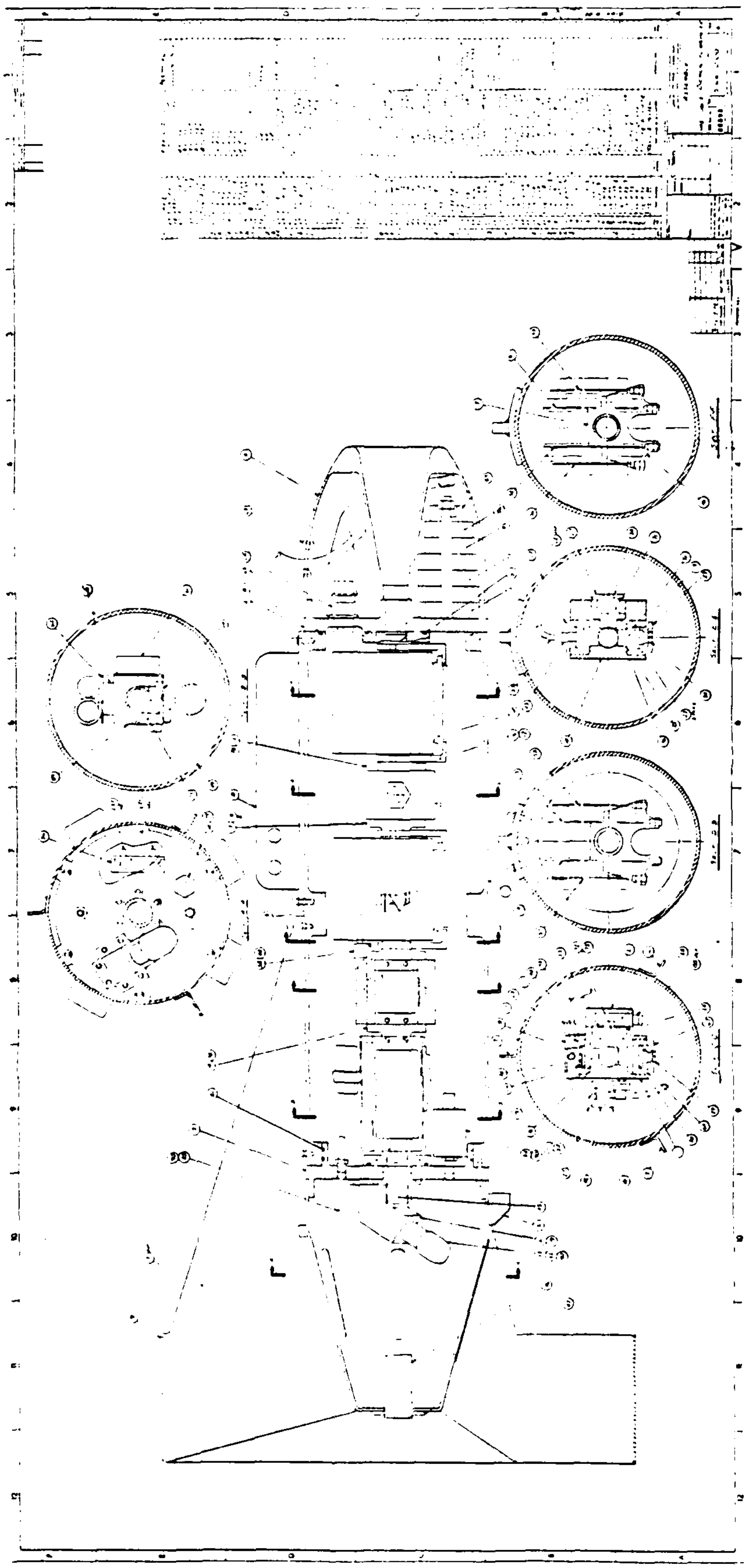
The system has had an initial at-sea test aboard the Coast Guard Ship "Evergreen". During this test, the basic design areas were evaluated: towing configuration, sensor stability, and background levels. During this test, no attempt was made to determine the in-situ sensitivity and accuracy of the system.

The system has been delivered to the Coast Guard R & D Center for further evaluation.

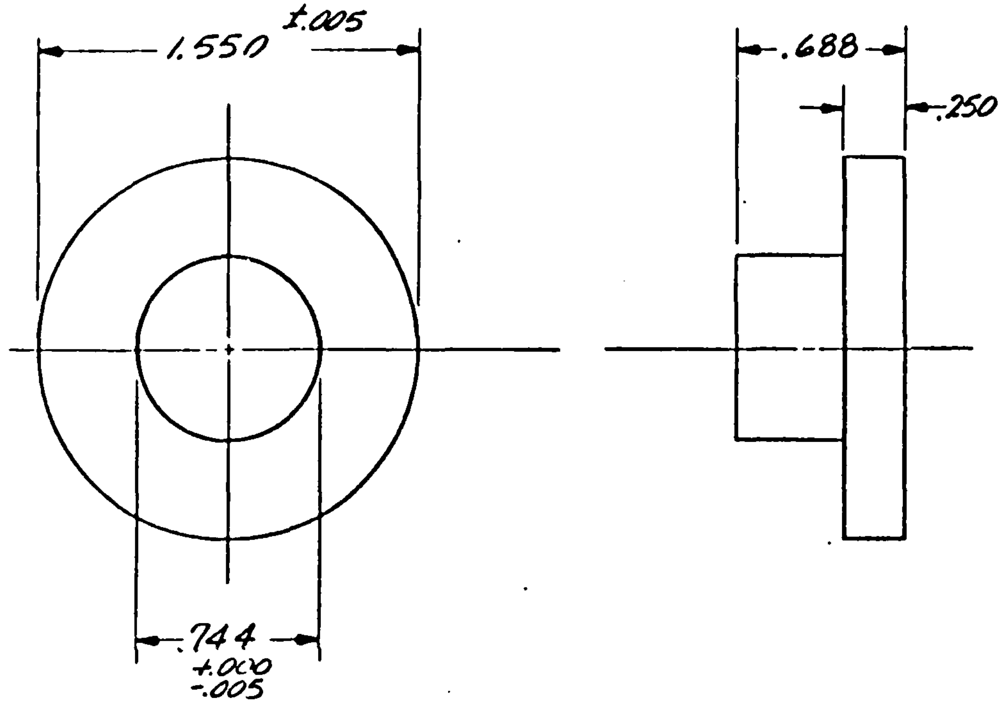
APPENDIX A

Drawings - Underwater Instrumentation Package.

Mechanical Assembly	5166-0100
Wiring Diagram	5166-0101
Windows - Optics Block	5166-0115
pH Probe	5166-0116
Logarithmic Amplifier - Turbidity	5166-0141
Temperature/Depth Conditioning	5166-0151
Lamp Control	5166-0161
Auxiliary Electronics	5166-0171
Voltage Regulator Assembly #1	5166-0181
Voltage Regulator Assembly #2	5166-0191
Photomultiplier and High Voltage Power Supply Assembly	5166-0201
Logarithmic Amplifiers Fluorescence and Absorption	5166-0211
pH Probe Conditioning	5166-0231
Analog to Digital Converter	5154-0121
Multiplexer Control	5154-0141



REVISIONS				
ISSUE	BY & DATE	DESCRIPTION	CHK'D	APPROVED & DATE
b	2/26/80 CJK	CHANGED MAT'L FROM COMMERICAL GRADE UV QUARTZ, 90% TRANSMISSION OF UV, 2600Å	CJK 2/26/80	



NOTES:

1. PROPOSED MATERIAL: AMERCIL; SUPERCIL 1, ULTRAVIOLET FINISH WINDOWS TO BE USED @2537Å AND LARGER WAVELENGTHS
2. PLATE GLASS SURFACE QUALITY

MATERIAL: SEE NOTE 1

FINISH: SEE NOTE 2

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES

DECIMAL TOL: XX = ±.03, XXX = ±.010 | FRACTIONS ±1/64 | ANGLES ±1/2°

	NAME	DATE
DRAWN BY	C.J. KARDIAN	1/7/80
CHECKED		

RELEASE: INITIAL | FINAL

PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER. NO
5166-0115			

USAGE

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
8621 GEORGIA AVENUE SILVER SPRING MARYLAND

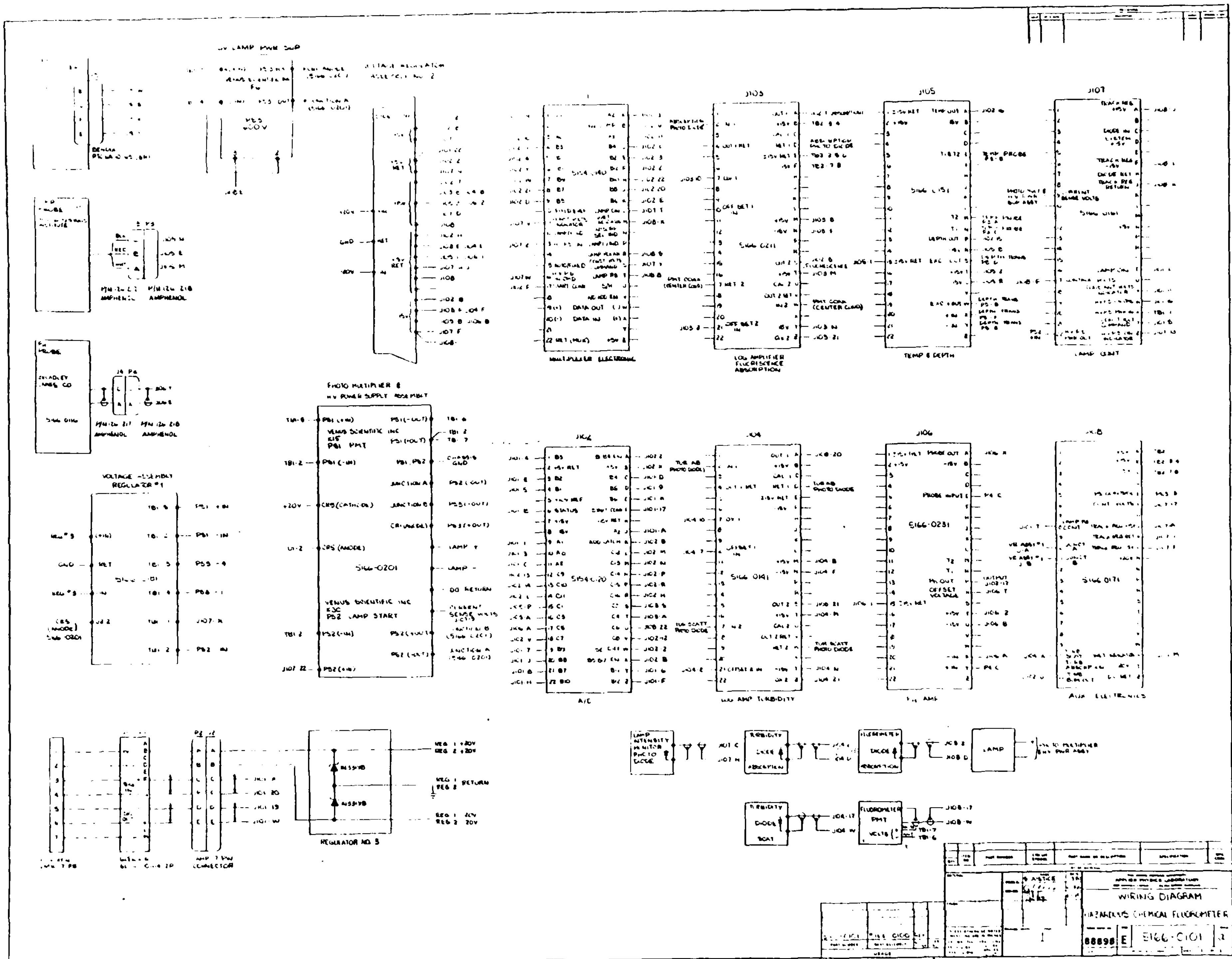
WINDOW
OPTICS BLOCK
HAZARDOUS CHEMICAL FLUOROMETER

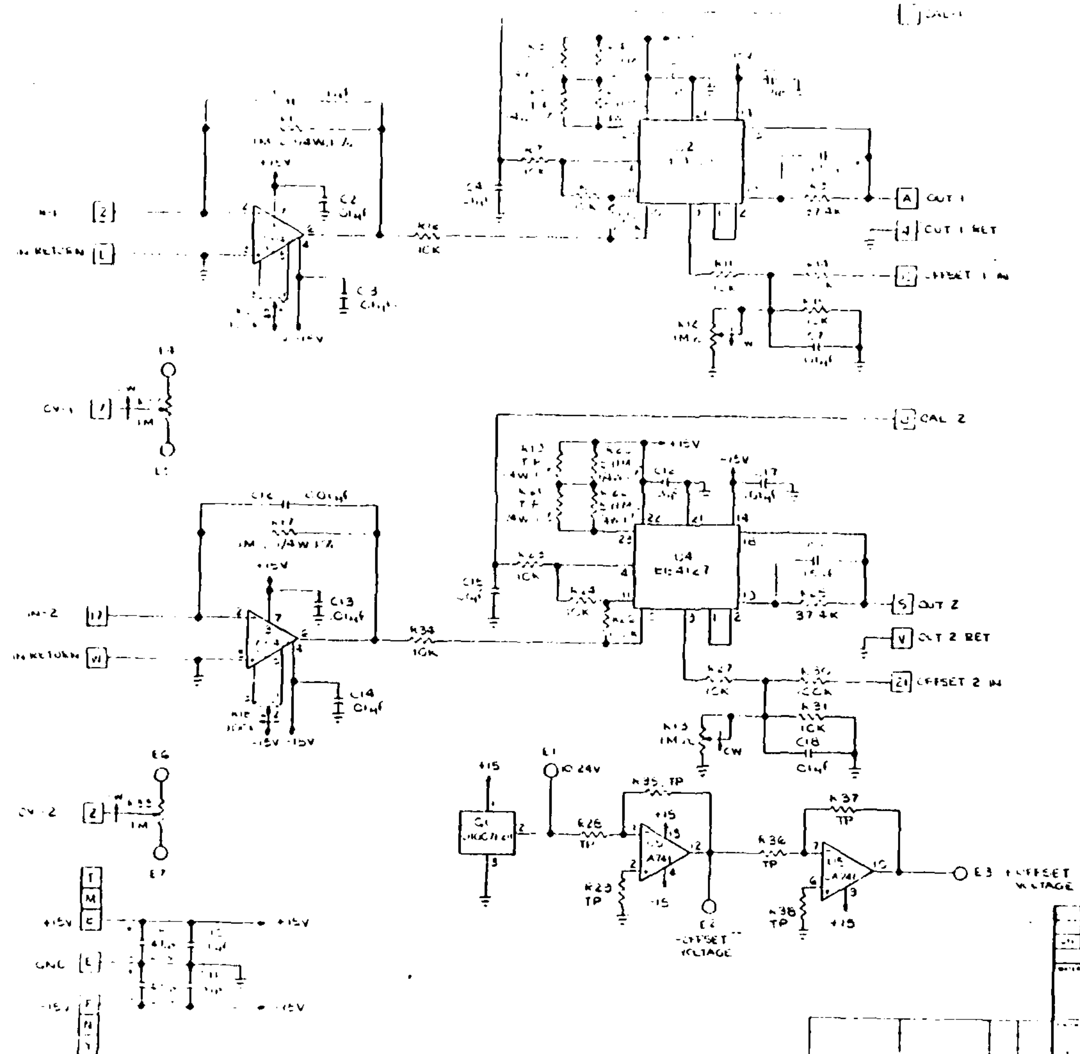
CODE IDENT NO	SIZE		ISSUE
88898	B	5166-0115	b

SCALE 2:1 — DO NOT SCALE PRINT — SHEET 1 OF 1

5166-0115 SHEET 1

FORM #EED-201


WIRING DIAGRAM
HAZARDOUS CHEMICAL FLUOROMETER
88898 E 5166-C101
UV LAMP PWR SUP
VOLTAGE REGULATOR ASSEMBLY NO. 2
PHOTO MULTIPLIER & HV POWER SUPPLY ASSEMBLY
VENUS SCIENTIFIC INC
5166-0201
VOLTAGE ASSEMBLY REGULATOR #1
REGULATOR NO. 3
J105
J107
J104
J106
J108
MULTIPLEXER ELECTRONIC
LOG AMPLIFIER FLUORESCENCE ABSORPTION
TEMP & DEPTH
LAMP UNIT
A/C
LOG AMP TURBIDITY
AUX ELECTRONICS
LAMP
TURBIDITY
FLUOROMETER
PMT
LAMP INTENSITY MONITOR PHOTO DIODE
AMPHENOL



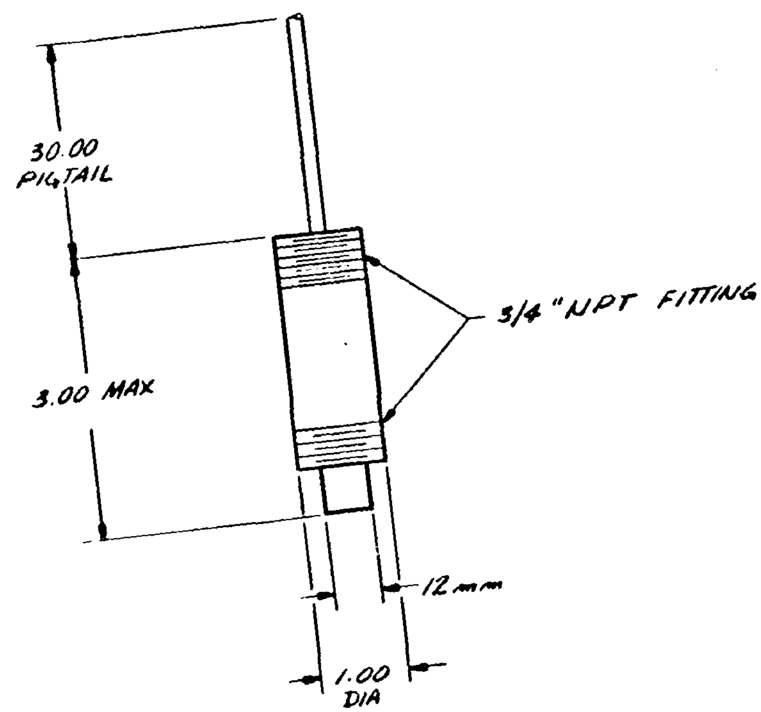
NOTES:
1. [illegible]
2. E2 & E3 PROVIDE VOLTAGE TO R32 (E4 & E5) & R33 (E6 & E7)
3. TAILOR RESISTORS ASSOCIATED WITH U5 ARE ADJUSTED TO DESIRED OFFSET VOLTAGES

APPLIED PHYSICS LABORATORY

SCHEMATIC
(TURBIDITY)
PHOTO DIODE [illegible] AMPLIFIER
[illegible]

88898 D

A



NOTES

1. BROADLEY-JAMES CORPORATION
   1714 SOUTH LYON STREET
   SANATA ANA, CALIFORNIA 92705
2. PH PROBE WITH REFERENCE ELECTRODE AND MEASURING ELECTRODE POTTED INTO A PVC HOUSING WITH 3/4" N.P.T. FITTINGS. 1" OUTSIDE DIAMETER X 3.0" OVERALL LENGTH.
   DIAMETER X 3.0" OVERALL LENGTH.
3. PH RANGE 0-14.
   TEMPERATURE RANGE -5°TO 80°C
   PRESSURE RANGE 150PSI
   REFERENCE TO BE GEL-FILLED Ag-Ag CL

QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

LIST OF MATERIAL

MATERIAL

FINISH

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DECIMAL TOL XX = ± .03 | FRACTIONS ± 1/64

DRAWN BY: C. J. KARDIAN | DATE: 2/76

CHECKED

RELEASE INITIAL | FINAL

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING MARYLAND

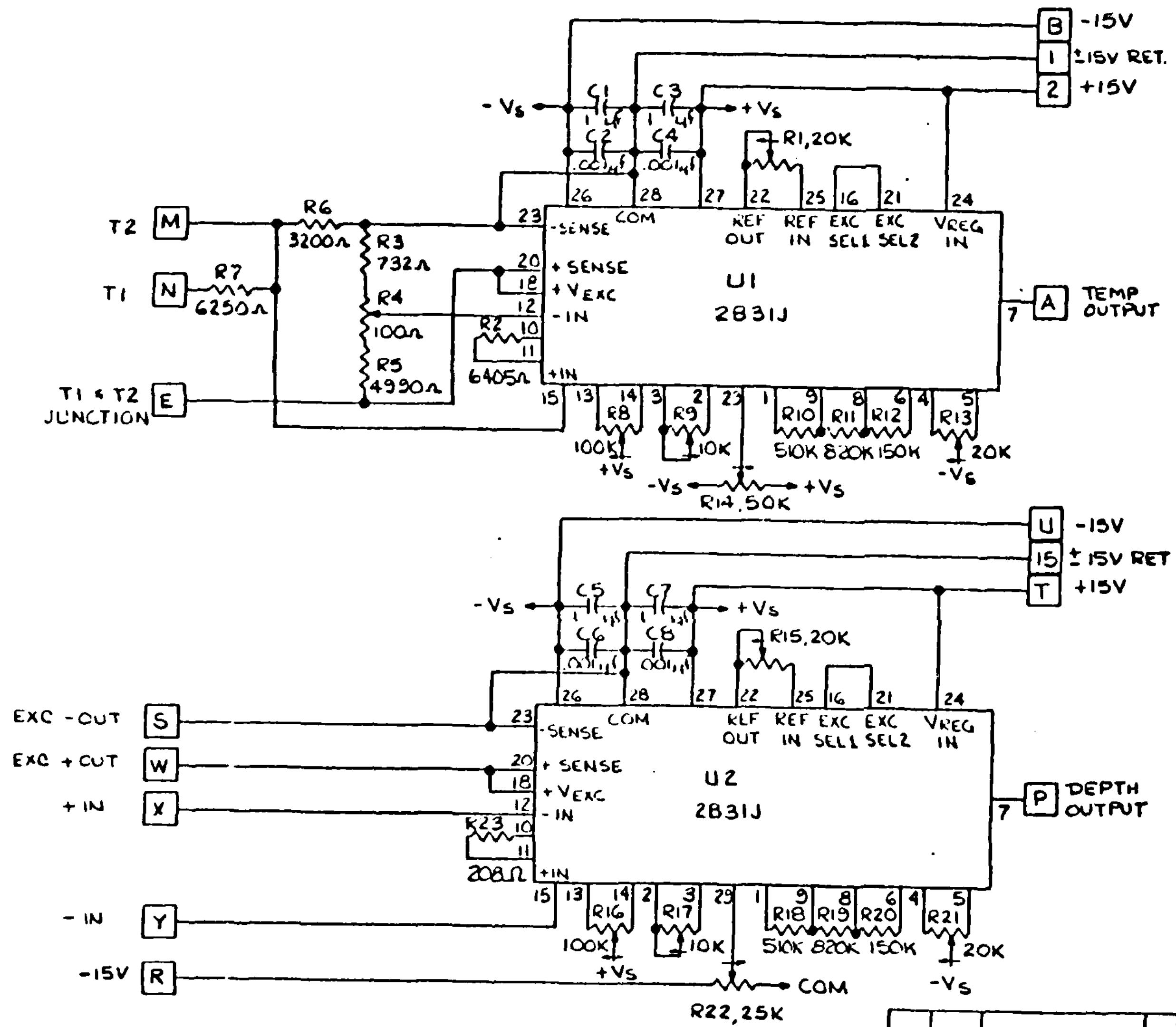
PH PROBE

HAZARDOUS CHEMICAL FLUOROMETER

CODE IDENT NO	SIZE		ISSUE
88898	C	5166-0116	a

PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER NO
5166-0116	5166-0100	1	—

5166-0116



QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

LIST OF MATERIAL

MATERIAL

FINISH

DRAWN BY B. LONG 5-2-71

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
DEPTH & TEMPERATURE
SENSOR CONDITIONING
HAZARDOUS CHEMICAL FLUOROMETER

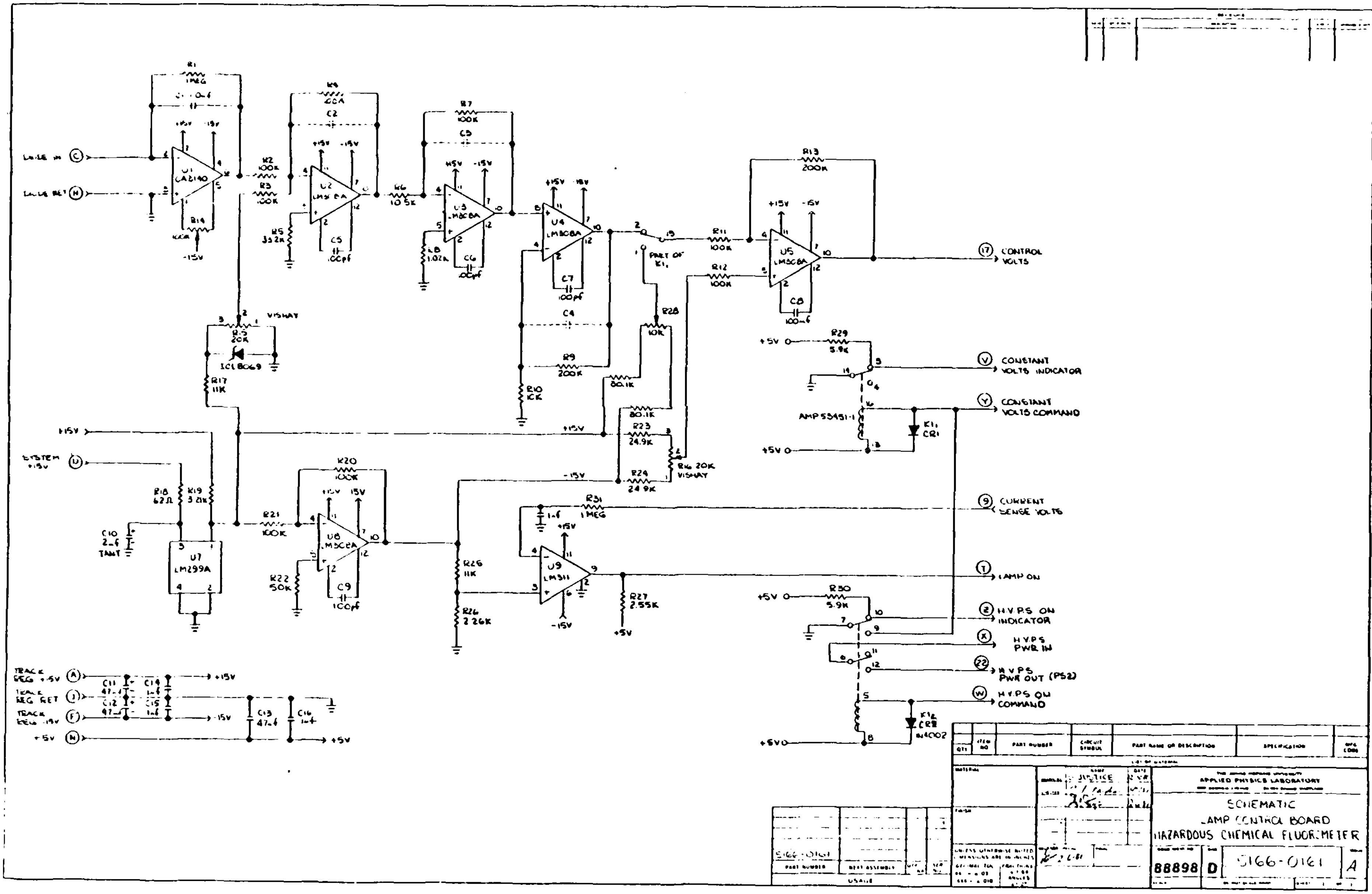
UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DECIMAL TOL XX = ±.03 XXX = ±.010
FRACTIONS ±1/64 ANGLES ±1/2°

5166-0151	5166-0150	REF	
PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER NO
USAGE			

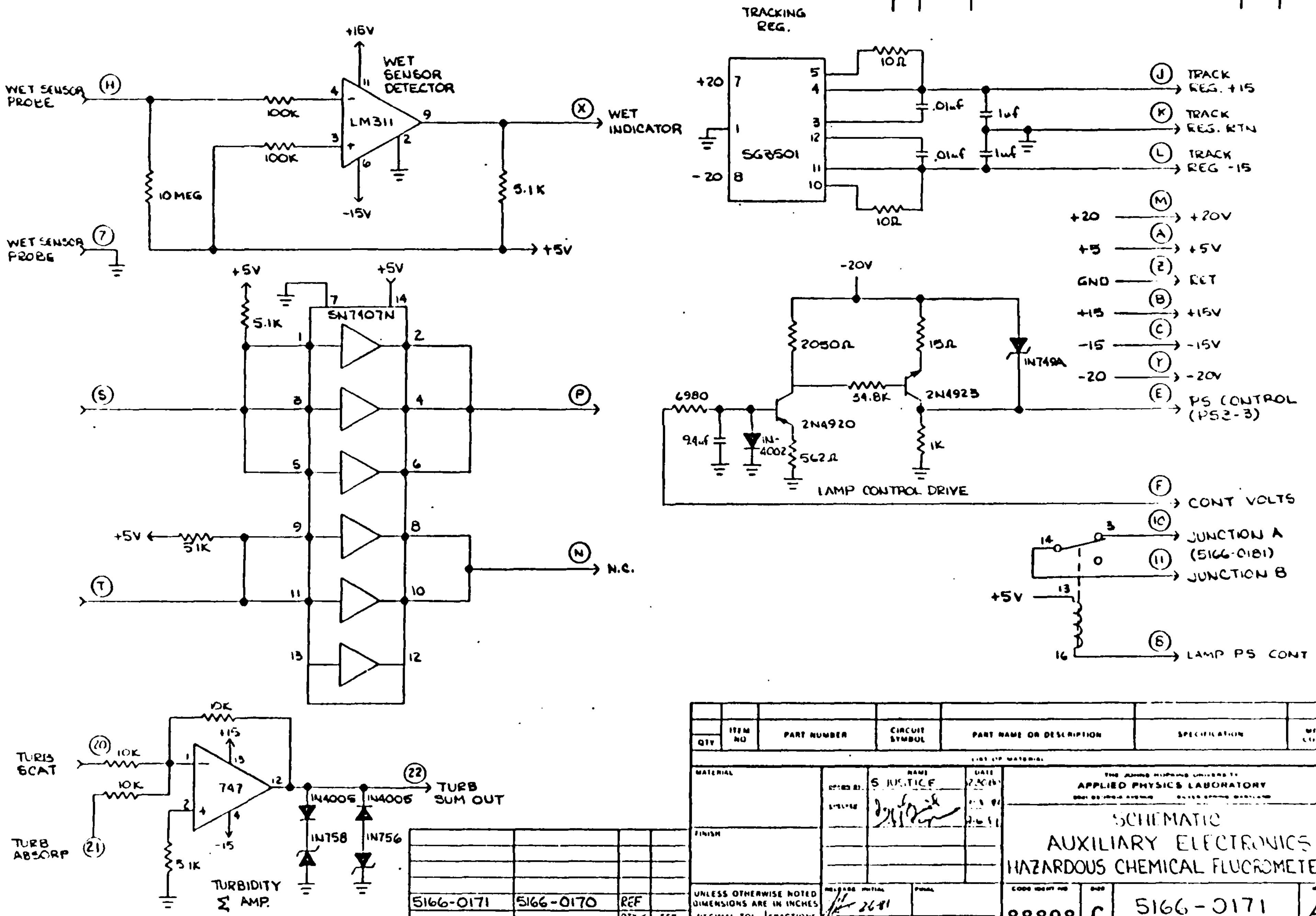
CODE IDENT NO	SIZE		ISSUE
88898	C	5166-0151	A

SCALE | DO NOT SCALE PRINT | SHEET OF

5166-0151



SCHEMATIC
LAMP CONTROL BOARD
HAZARDOUS CHEMICAL FLUORIMETER
APPLIED PHYSICS LABORATORY
88898 D 5166-0161 A
CONTROL VOLTS
CONSTANT VOLTS INDICATOR
CONSTANT VOLTS COMMAND
CURRENT SENSE VOLTS
LAMP ON
H.V.P.S. ON INDICATOR
H.V.P.S. PWR IN
H.V.P.S. PWR OUT (PS2)
H.V.P.S. ON COMMAND
SYSTEM +15V
TRACK REG +5V
TRACK REG RET
TRACK REG -15V
PART OF K1
AMP 55451-1
VISHAY
U1 CA3140
U2 LM308A
U3 LM308A
U4 LM308A
U5 LM308A
U7 LM299A
U8 LM308A
U9 LM311
R1 1MEG
R13 200K
R9 200K
R27 2.55K
R31 1MEG
R16 20K VISHAY
R23 24.9K
R24 24.9K
1CL8069



5166-0171	5166-0170	REF	
PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER NO
USAGE			

QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

LIST OF MATERIAL

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DECIMAL TOL XX = ±.03 XXX = ±.010
FRACTIONS ±1/64 ANGLES ±1/2°

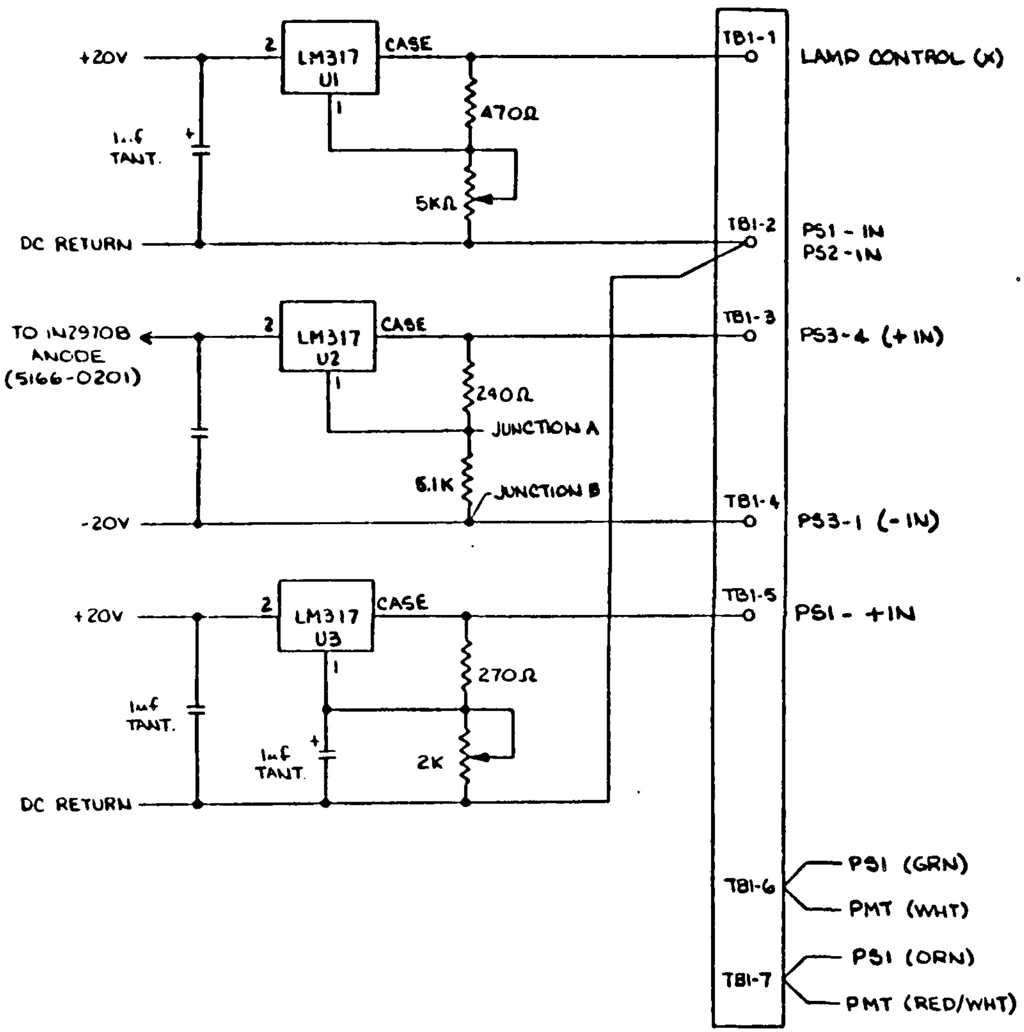
S. JUSTICE

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
AUXILIARY ELECTRONICS
HAZARDOUS CHEMICAL FLUOROMETER

CODE IDENT NO	SIZE		
88898	C	5166-0171	A

5166-0171



QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

LIST OF MATERIAL

PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER NO
5166-0181	5166-0180	REF	

USAGE

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DECIMAL TOL. XX = ±.03 XXX = ±.010
FRACTIONS ±1/64 ANGLES ±1/2°

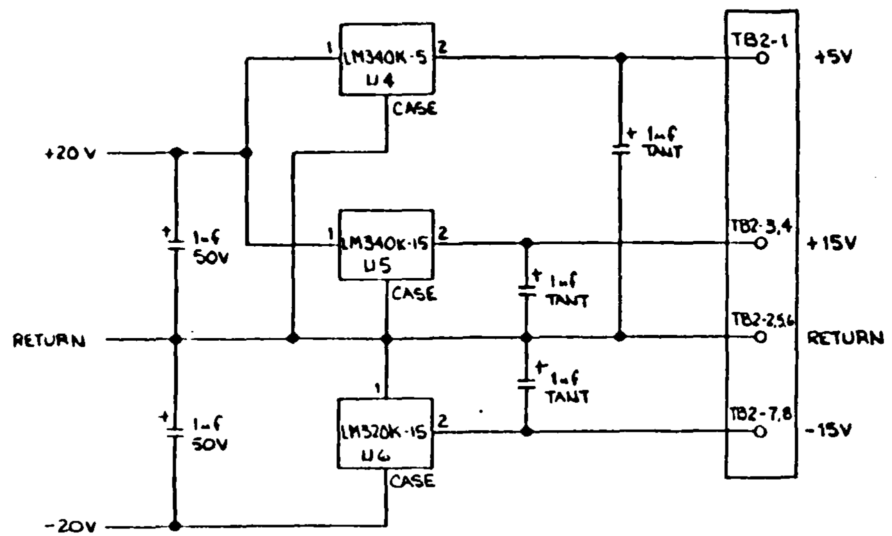
NAME: S. JUSTICE — DATE: 29-80

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
VOLTAGE REGULATOR ASSEMBLY #1
HAZARDOUS CHEMICAL FLUOROMETER

CODE IDENT NO 88898 | SIZE C | 5166-0181 | REV A

DO NOT SCALE PRINT — SHEET 1 OF 1



QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

LIST OF MATERIAL

PART NUMBER	NEXT ASSEMBLY	QTY	SER NO
5166-0191	5166-0190	REF	

USAGE

MATERIAL

FINISH

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES

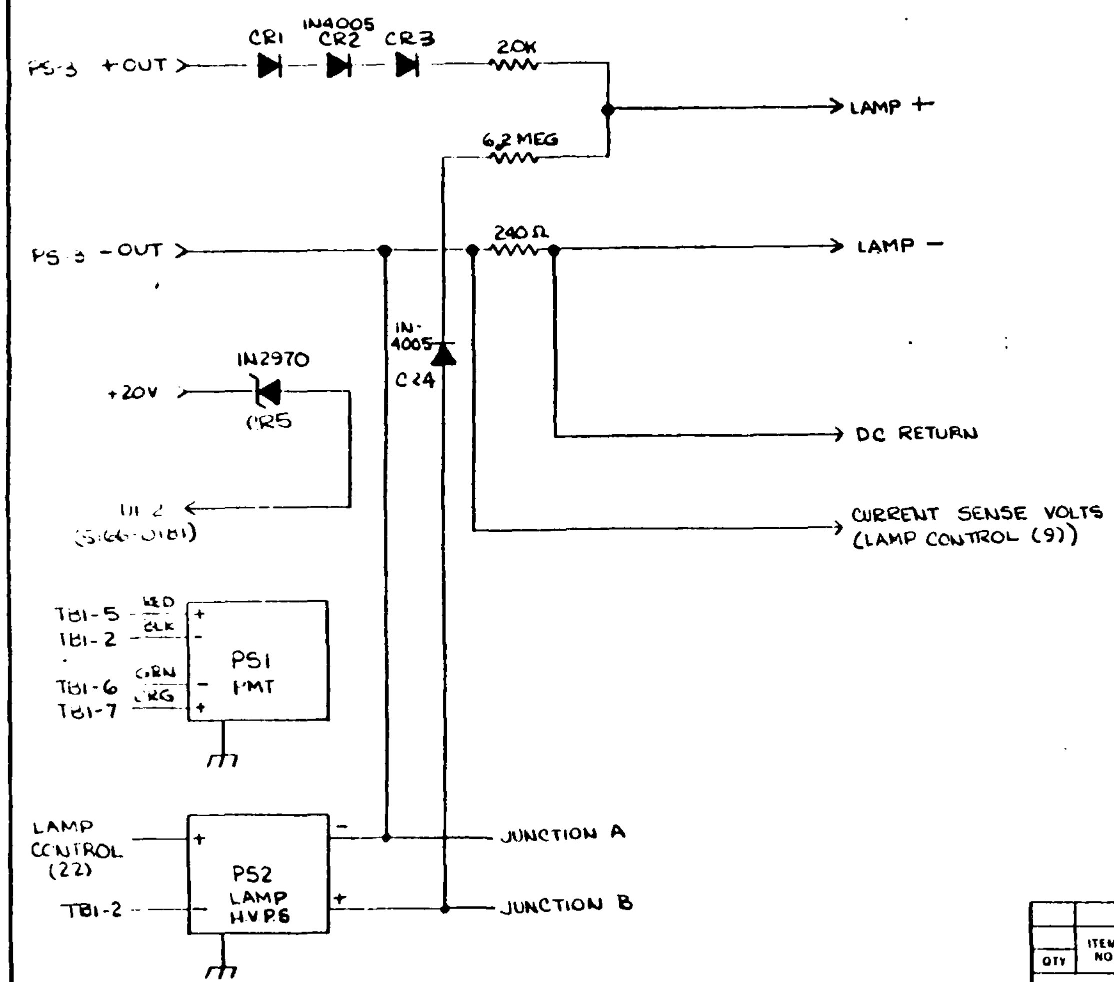
DECIMAL TOL XX = ±.03 XXX = ±.010 | FRACTIONS ±1/64 ANGLES

NAME: S. JUSTICE — DATE: 12 11 83

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
VOLTAGE REGULATOR ASSEMBLY #2
HAZARDOUS CHEMICAL FLUOROMETER

CODE IDENT NO: 88898 | SIZE: C | 5166-0191 | A



REVISIONS

ISSUE	BY & DATE	DESCRIPTION	CHECK	APPROVED & DATE

LIST OF MATERIAL

QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

PART NUMBER	NEXT ASSEMBLY	QTY/NA	SER NO
5166-0201	5166-0200	REF	

USAGE

MATERIAL

FINISH

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
DECIMAL TOL XX = ± .03 XXX = ± .010
FRACTIONS ± 1/64 ANGLES ± 1/2°

DRAWN BY: S. JUSTICE 1/16/81
CHECKED:
RELEASE INITIAL: 2-6-81
FINAL

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
8621 GEORGIA AVENUE SILVER SPRING MARYLAND

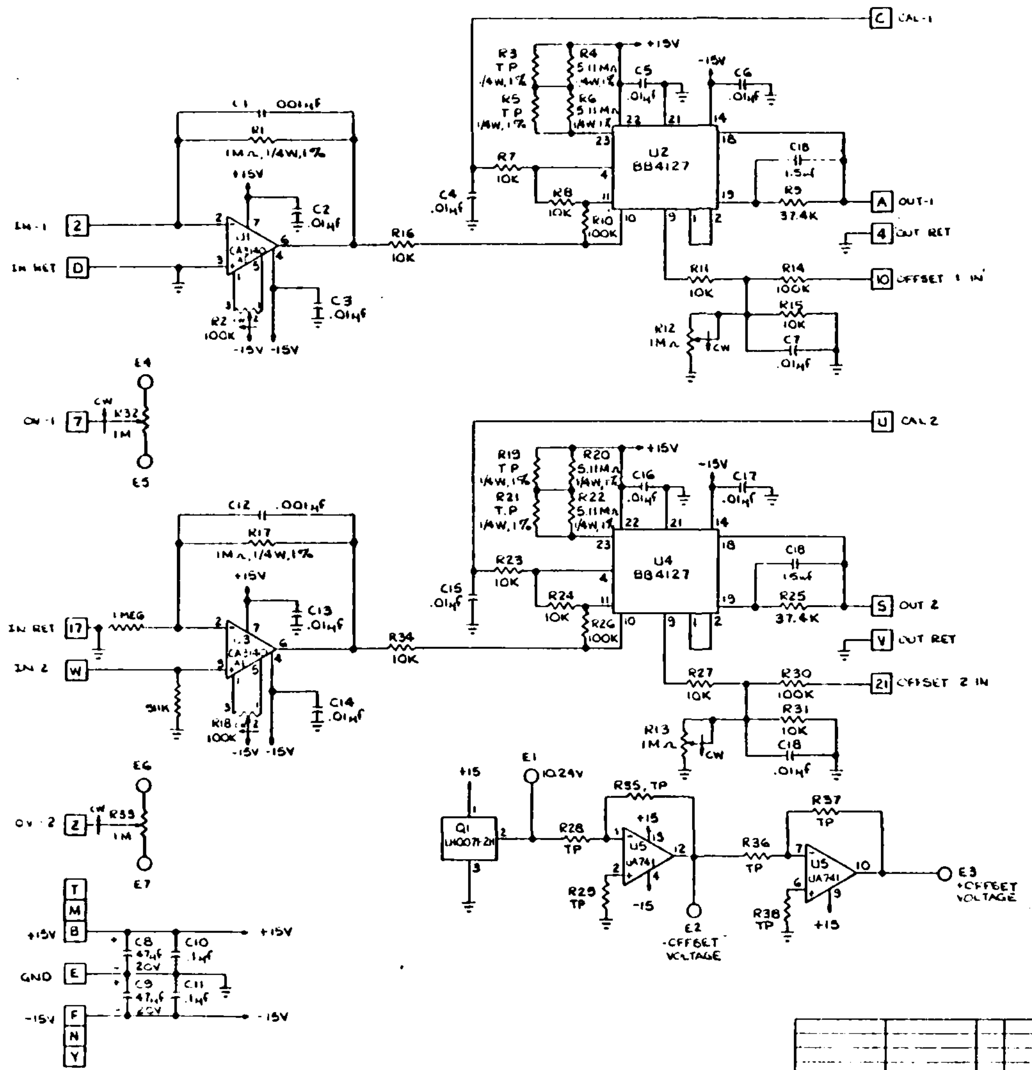
SCHEMATIC
PHOTO MULTIPLIER & HV PWR SUP. ASSY
HAZARDOUS CHEMICAL FLUOROMETER

CODE IDENT NO 88898 SIZE C 5166-0201 ISSUE A

SCALE DO NOT SCALE PRINT SHEET 1 OF 1

5166-0201

5166-0211

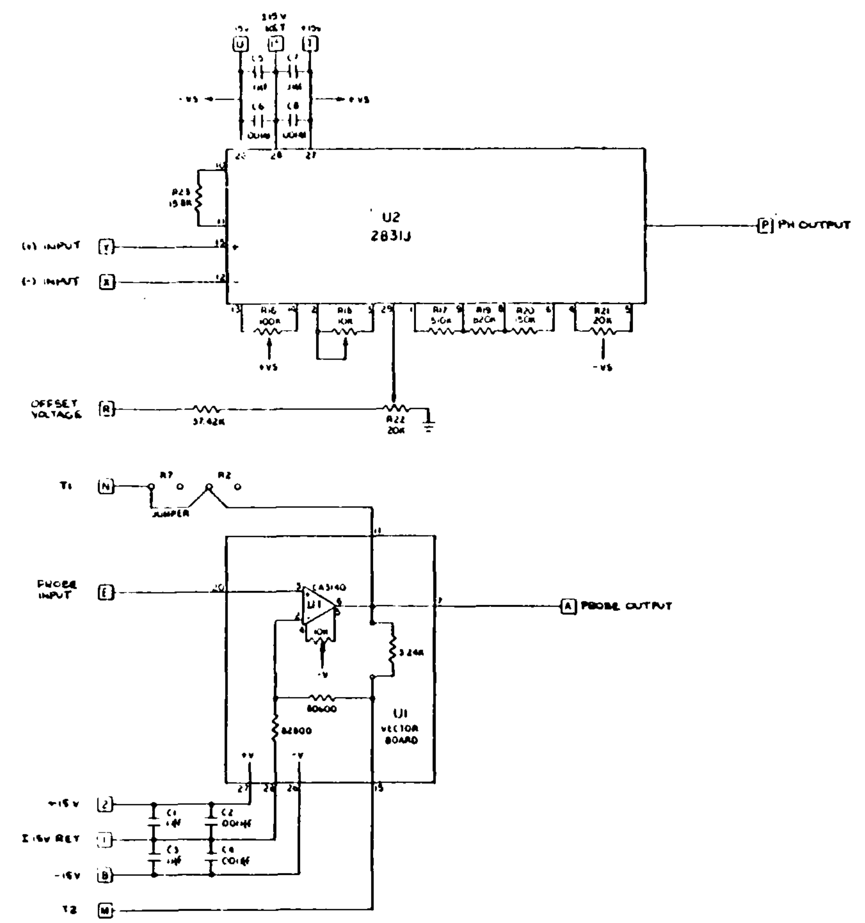


NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   ALL RES'S ARE 1/10W, 1%
2. E2 & E3 PROVIDE VOLTAGE TO R32 (E4 & E5) & R33 (E6 & E7).
3. TAILOR RESISTORS ASSOCIATED WITH U5 ARE ADJUSTED TO DESIRED OFFSET VOLTAGES.

APPLIED PHYSICS LABORATORY

SCHEMATIC

88898 D 5166-0211 A

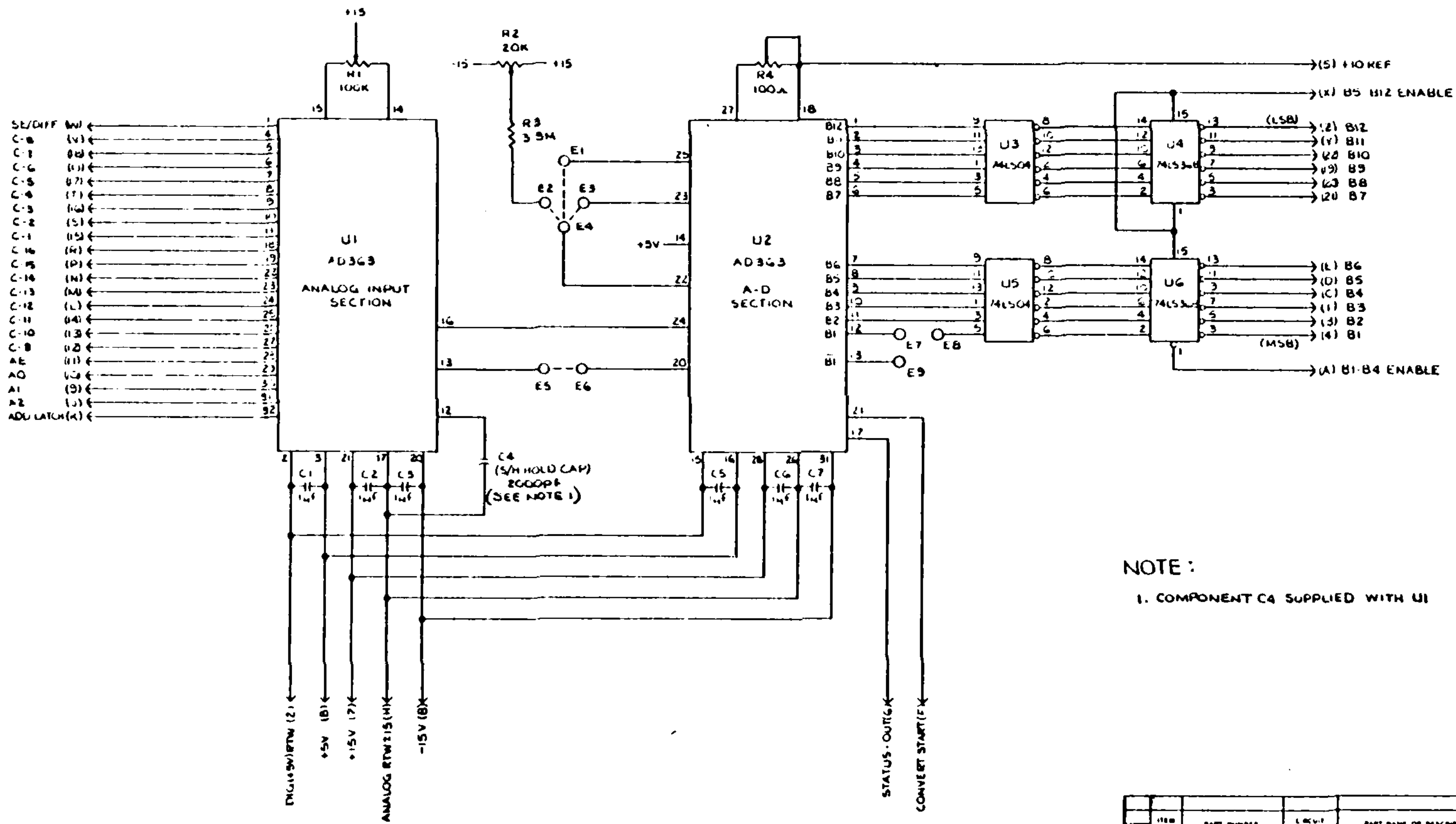


SCHEMATIC
PH SENSOR CONDITIONING
HAZARDOUS CHEMICAL FLOOR

APPLIED PHYSICS LABORATORY

88898 D 5166-0231 A

5166-0231 | 5166-0230 | REF



NOTE :

1. COMPONENT C4 SUPPLIED WITH U1

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
A-D CONVERTER
TCFS MULTIPLEXER

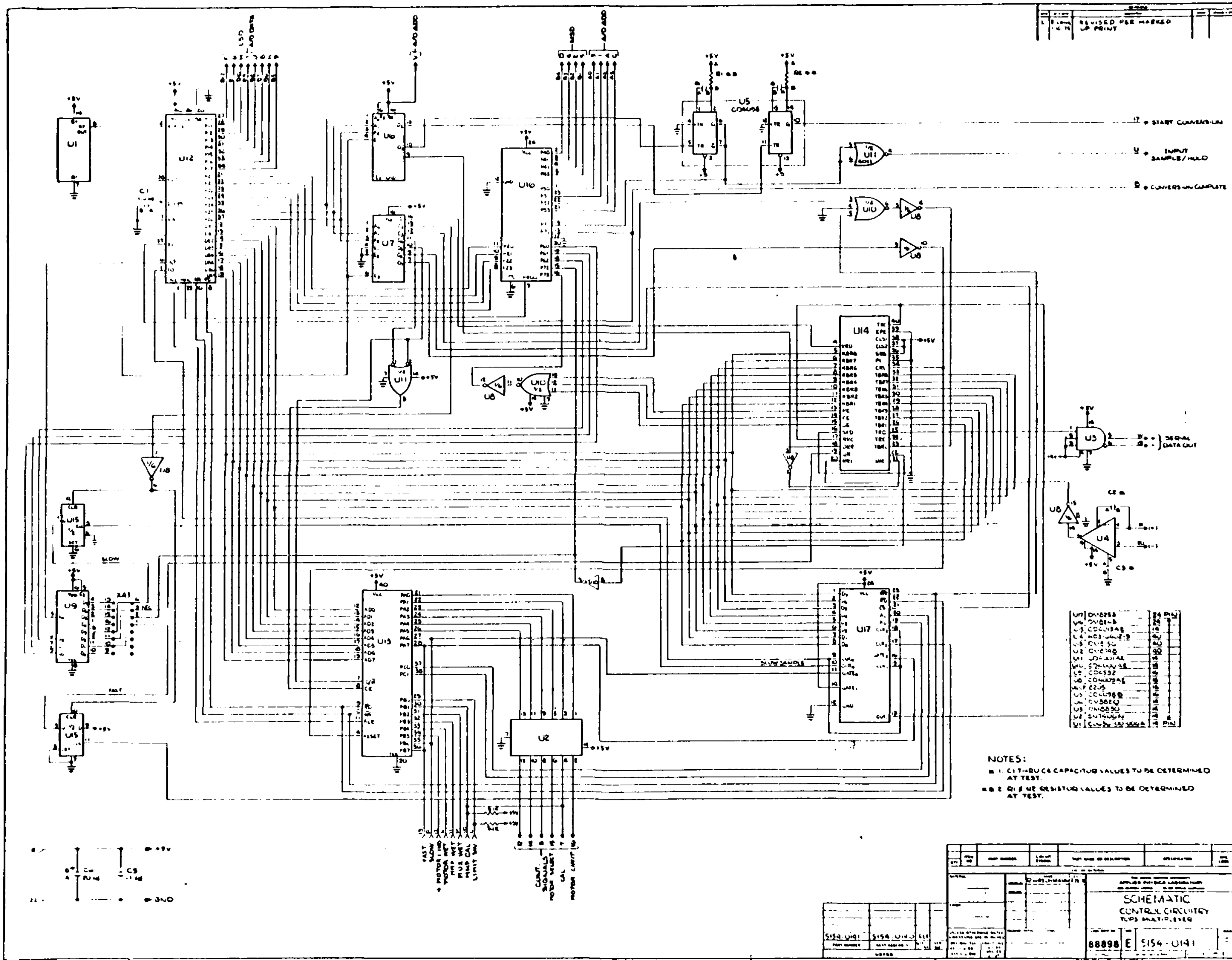
88898 D 5154-0121

5154-0121

5154-0120

USAGE

5154-0121



NOTES:

1. C1 THRU C4 CAPACITOR VALUES TO BE DETERMINED AT TEST.
2. R1 & R2 RESISTOR VALUES TO BE DETERMINED AT TEST.

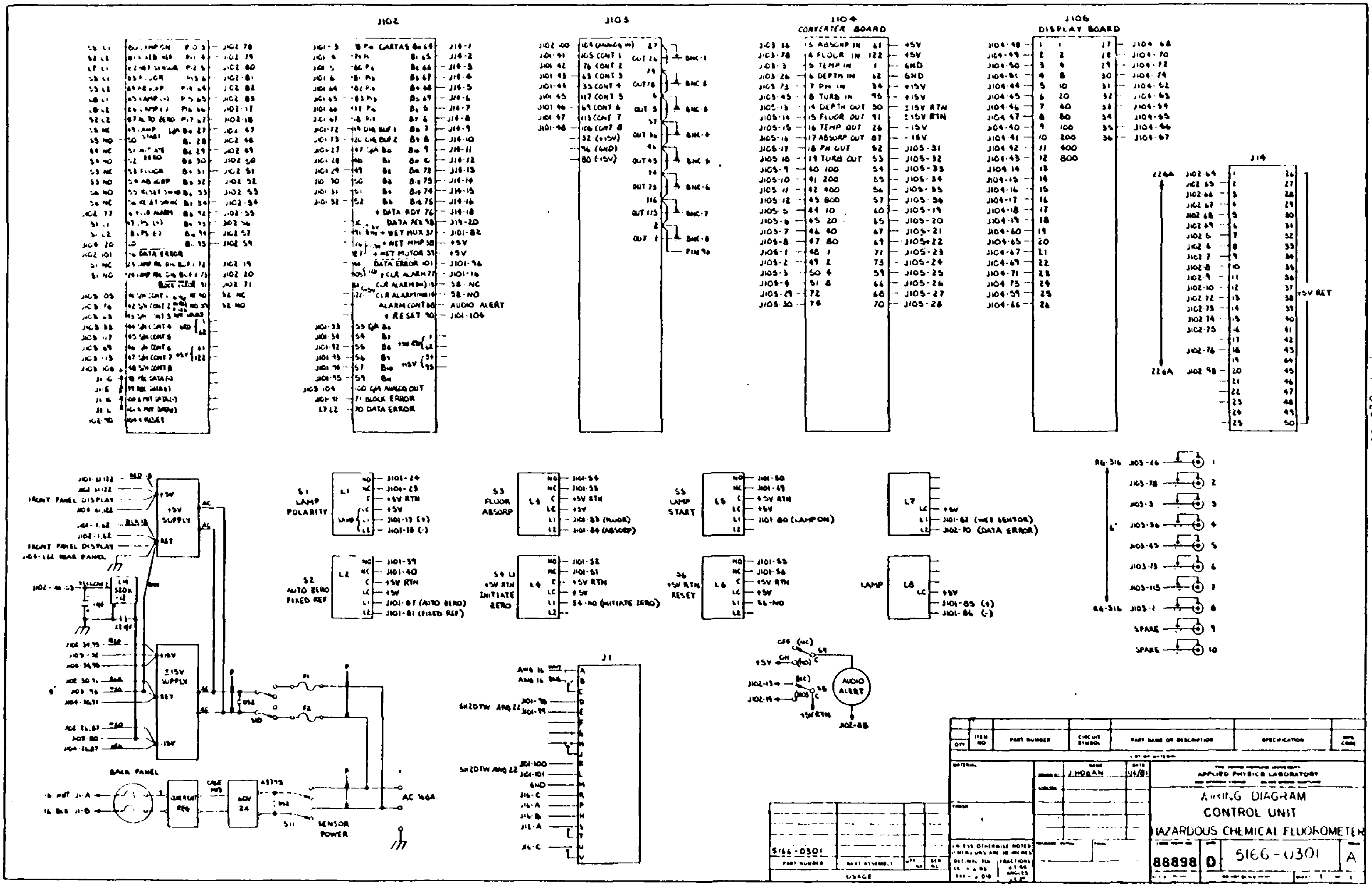
SCHEMATIC
CONTROL CIRCUITRY
TLPS MULTIPLEXER

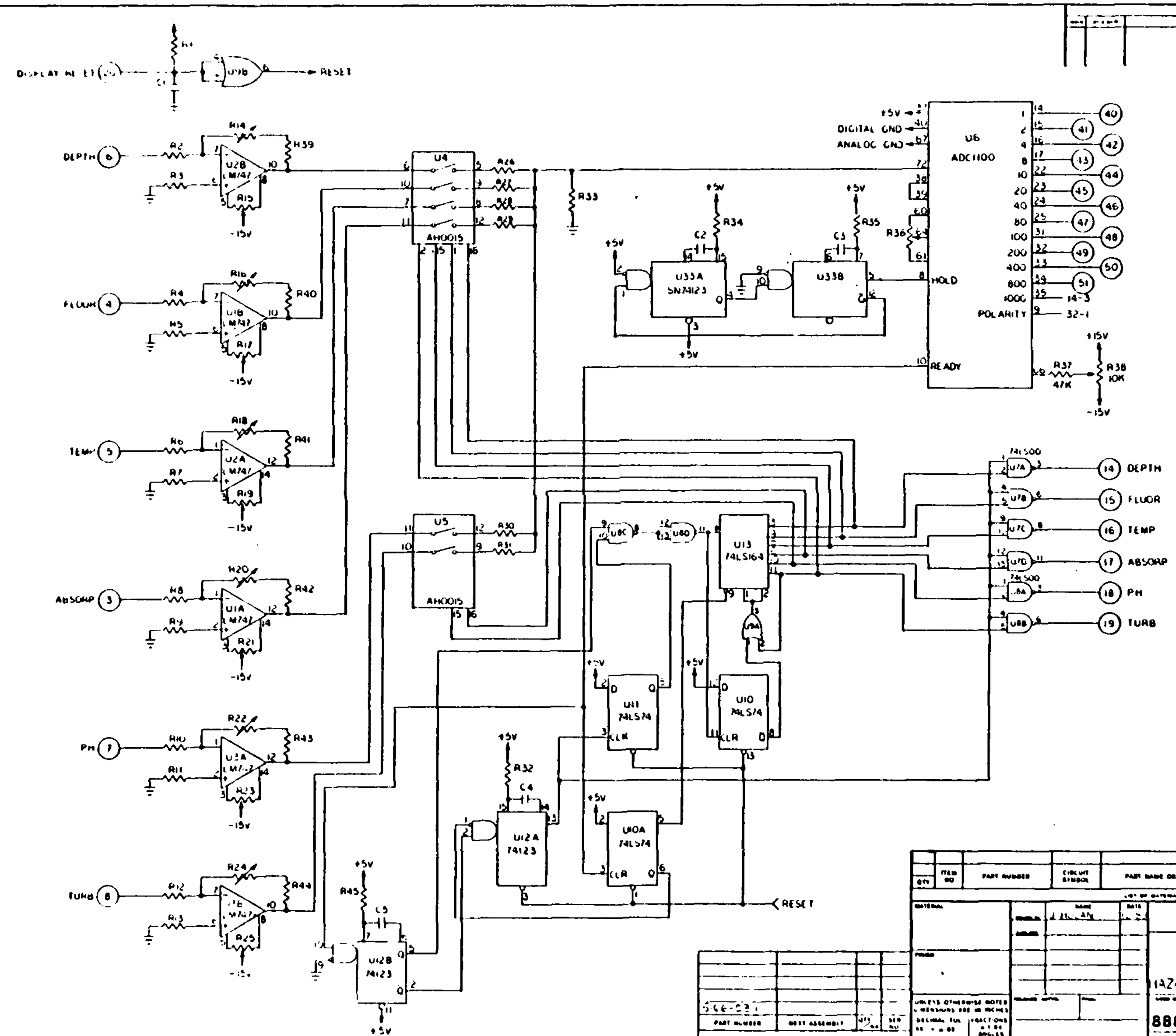
88898 E 5154-0141

APPENDIX B

Drawings - Shipboard Control Unit.

Control Unit Wiring Diagram	5166-0301
Display Control Board	5166-0311
Sample and Hold Circuits	5166-0321
Demultiplexer Board 1	5166-0331
Demultiplexer Board 2	5166-0341


J102
J103
J104
CONVERTER BOARD
J106
DISPLAY BOARD
J14
J1
S1 LAMP POLARITY
S2 AUTO ZERO FIXED REF
S3 FLUOR ABSORP
S4 INITIATE ZERO
S5 LAMP START
S6 RESET
LAMP
AUDIO ALERT
BACK PANEL
SENSOR POWER
AC 166A
±15V SUPPLY
+5V SUPPLY
FRONT PANEL DISPLAY
APPLIED PHYSICS LABORATORY
J. HOGAN
WIRING DIAGRAM
CONTROL UNIT
HAZARDOUS CHEMICAL FLUOROMETER
88898
D
5166-0301
A
5166-0301

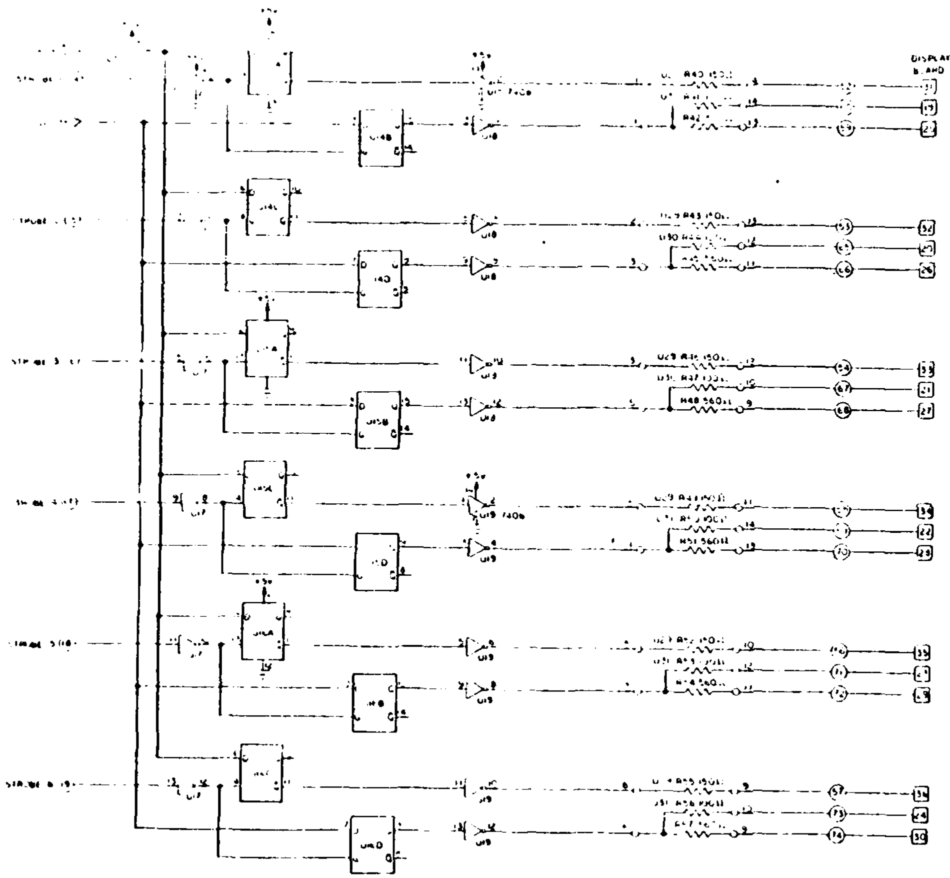


THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
DISPLAY BD
CONTROL UNIT
HAZARDOUS CHEMICAL FLUOROMETER

88898 D 5166-0311 A

5166-0311

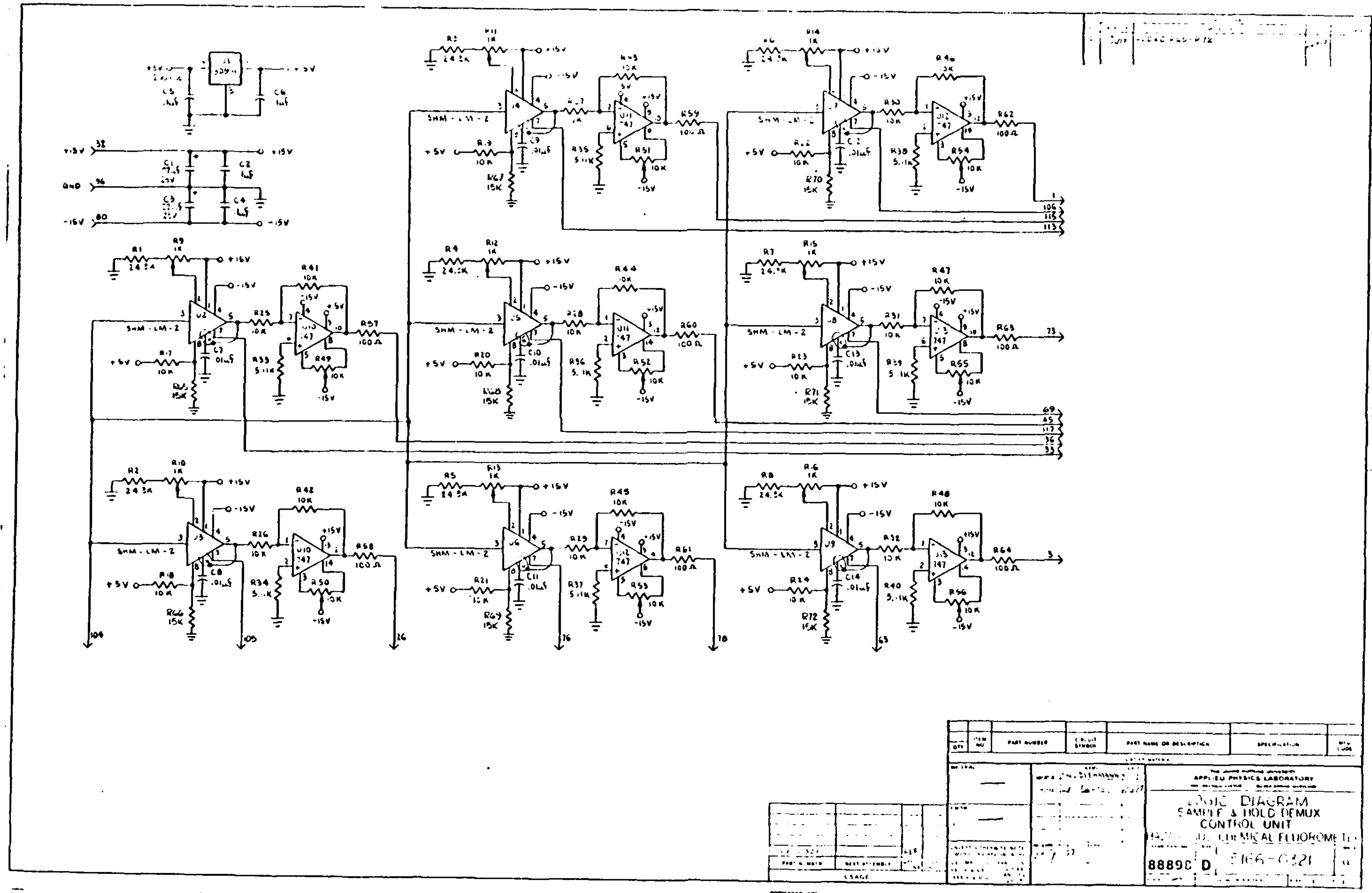


APPLIED PHYSICS LABORATORY

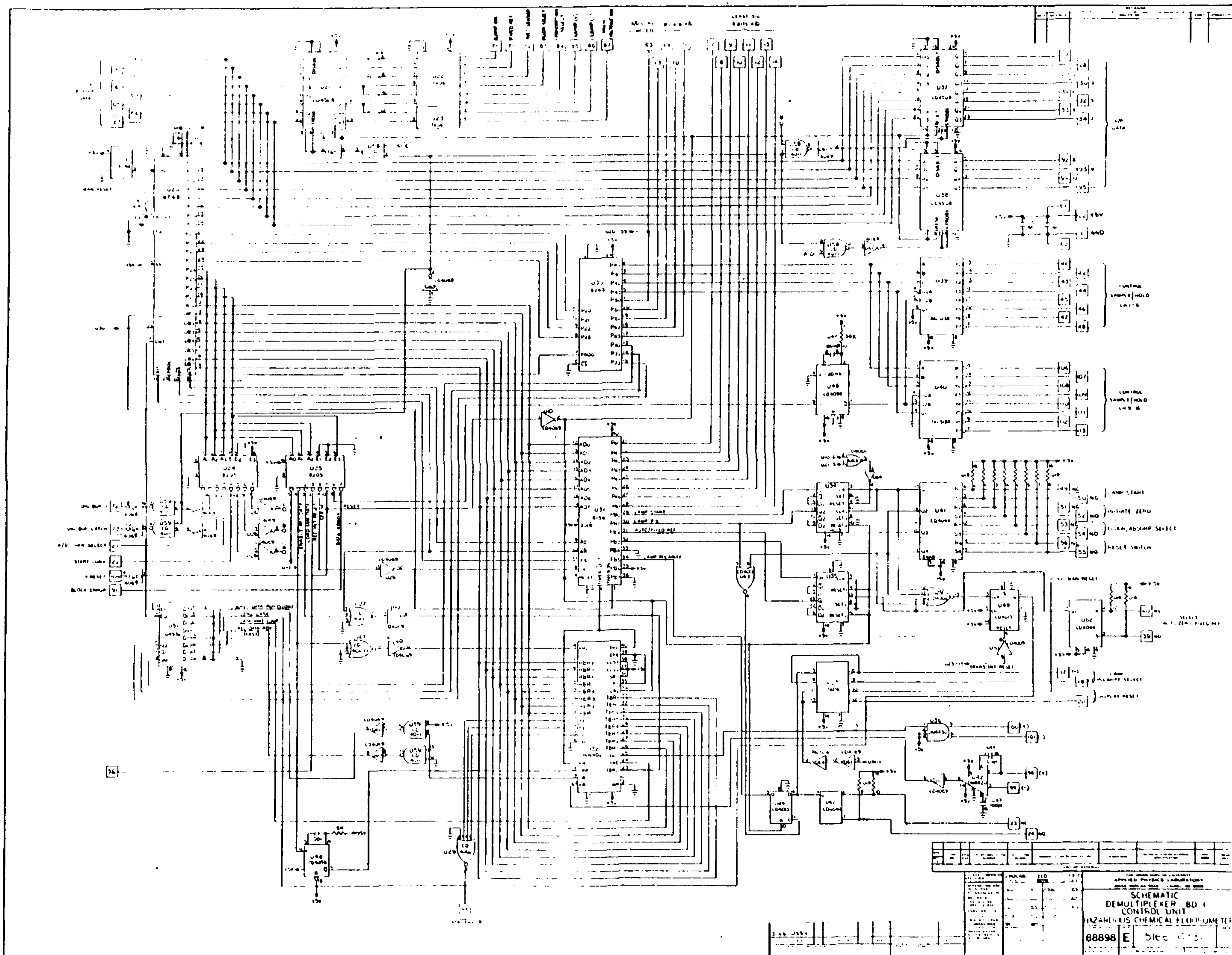
SCHEMATIC
DISPLAY BD
CONTROL UNIT

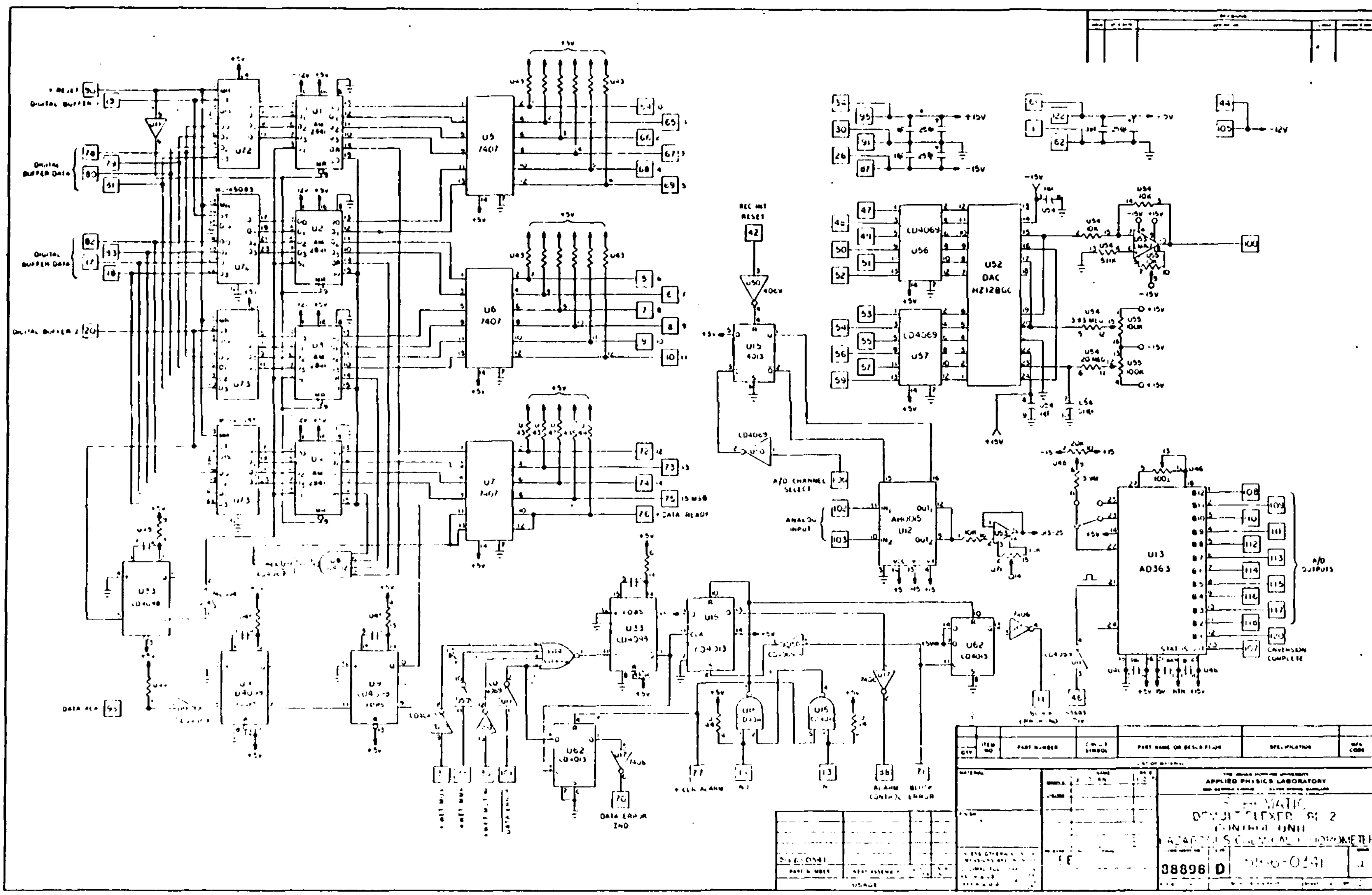
88898 D 5166-0311 A

5166-0311

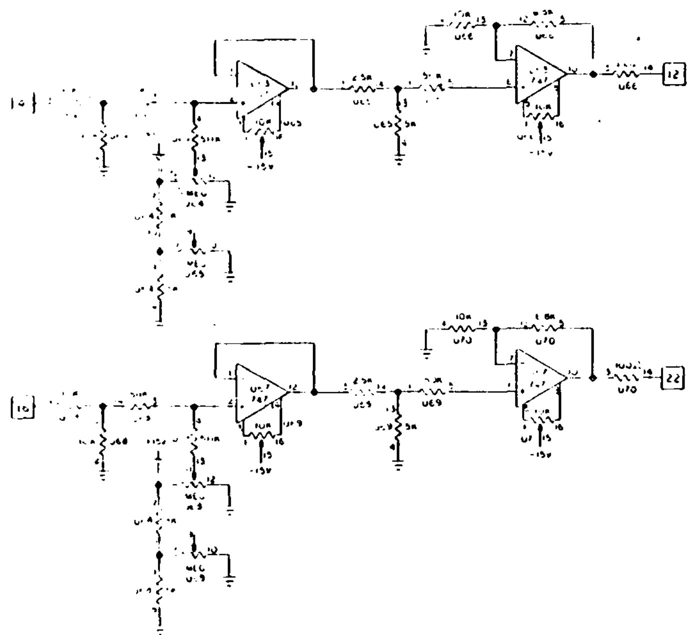


APPLIED PHYSICS LABORATORY
LOGIC DIAGRAM
SAMPLE & HOLD DEMUX
CONTROL UNIT
CHEMICAL FLUOROMETER
88898
D
5166-0321


SCHEMATIC
DEMULTIPLEXER BD 1
CONTROL UNIT
HAZARDOUS CHEMICAL FLUOROMETER
88898 E
LAMP START
INITIATE ZERO
FLUOR/ABSORP SELECT
RESET SWITCH
CONTROL SAMPLE/HOLD
+5V
GND



DIGITAL BUFFER DATA
DIGITAL BUFFER DATA
U5
7407
U6
7407
U7
7407
U52
DAC
HZ12BGC
CD4069
U56
CD4069
U57
REC INT RESET
U50
U15
4013
A/D CHANNEL SELECT
ANALOG INPUT
AM1015
U12
U13
AD363
A/D OUTPUTS
CONVERSION COMPLETE
15 MSB
DATA READY
U53
U62
CD4013
DATA ERROR IND
ALARM CONTROL
BUFFER ERROR
DATA ACK
APPLIED PHYSICS LABORATORY
38896 D



QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG CODE

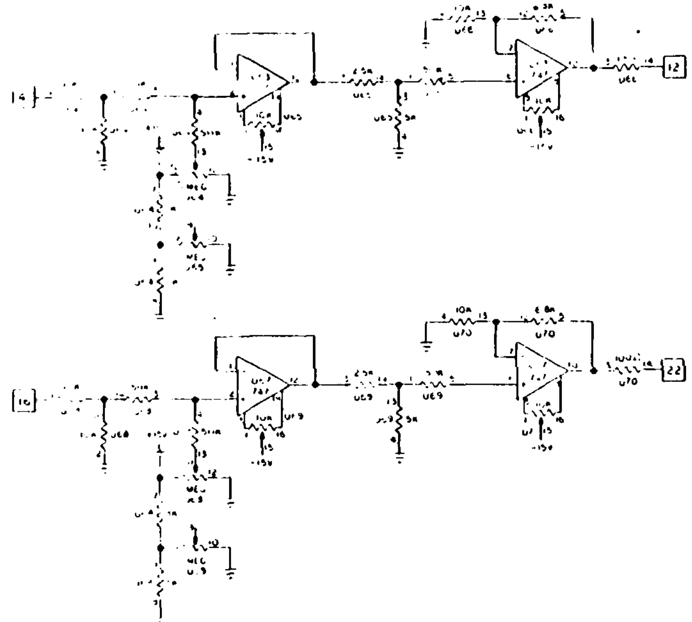
APPLIED PHYSICS LABORATORY

SCHEMATIC
DEMULTIPLEXER BD. 2
CONTROL UNIT
HAZARDOUS CHEMICAL FLUOROMETER

88898 D 5166-03-11

USAGE

5166-0341



QTY	ITEM NO	PART NUMBER	CIRCUIT SYMBOL	PART NAME OR DESCRIPTION	SPECIFICATION	MFG. CODE

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

SCHEMATIC
DEMULTIPLEXER BD. 2
CONTROL UNIT
HAZARDOUS CHEMICAL FLUOROMETER

88898 D 5166-03-11

5166-0341

END

FILMED

7-83

DTIC